Experience to date with L8

Curtis Woodcock, Zhe Zhu, Pontus Olofsson, Shixiong Wang, Chris Holden, Boston University

Cloud/Cloud Shadow/Snow Detection

Image Classification

Data quality (variograms)

Band 3 – Red

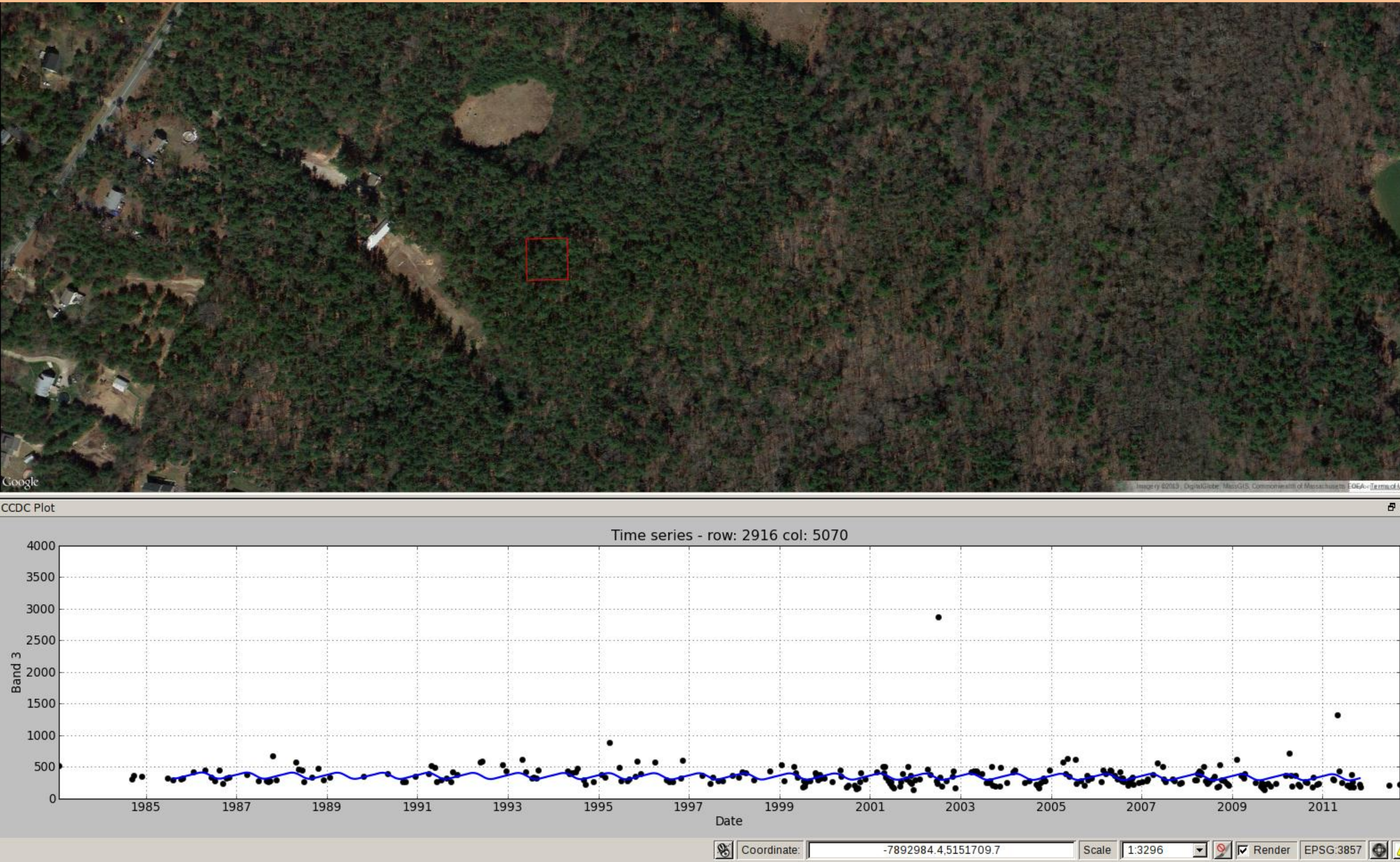
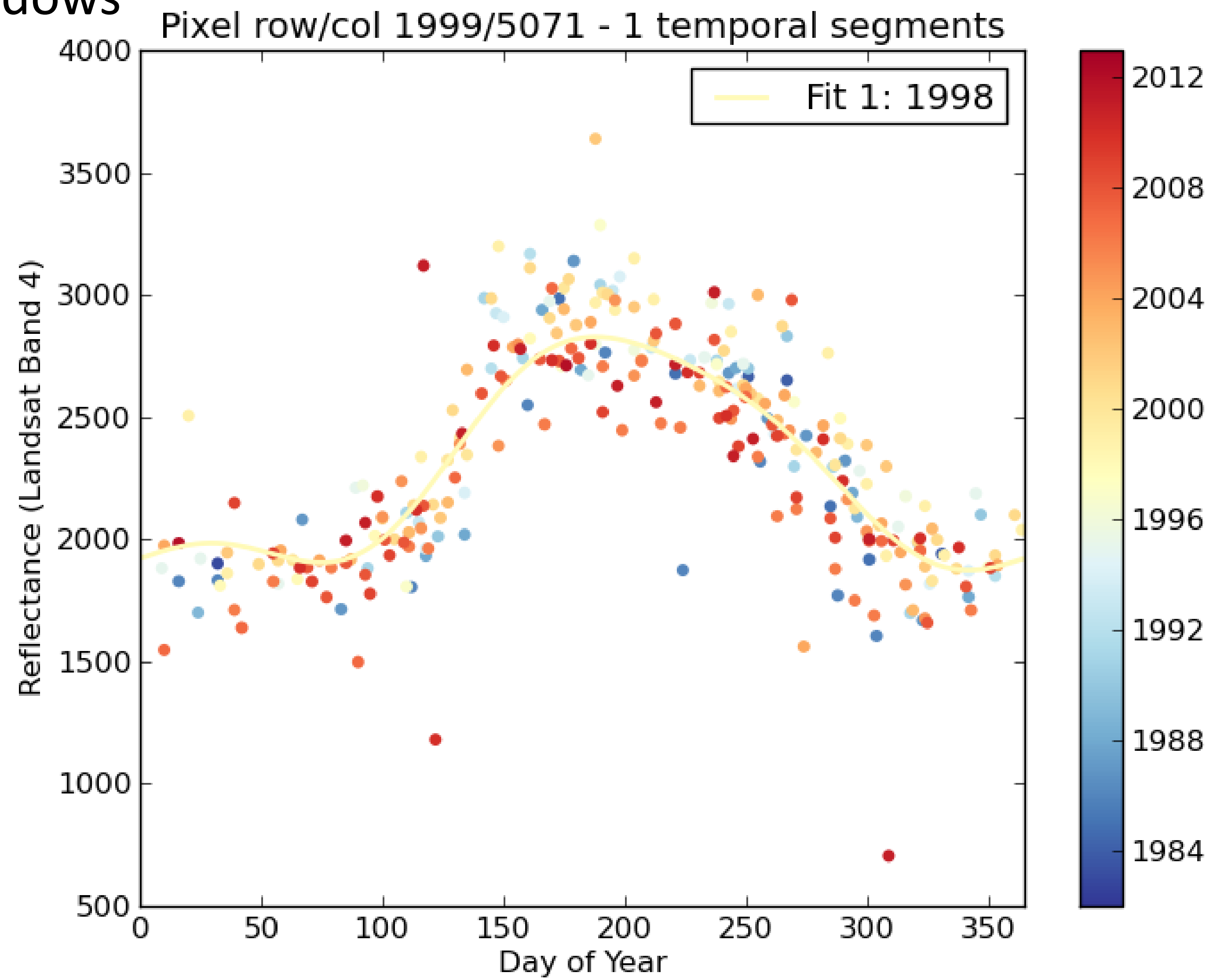


Image: Google Earth

Plot of virtually all available Landsat observations for a single pixel of a stable coniferous forest – the noisy values are observations influenced by undetected clouds and cloud shadows



Band 3 – Red

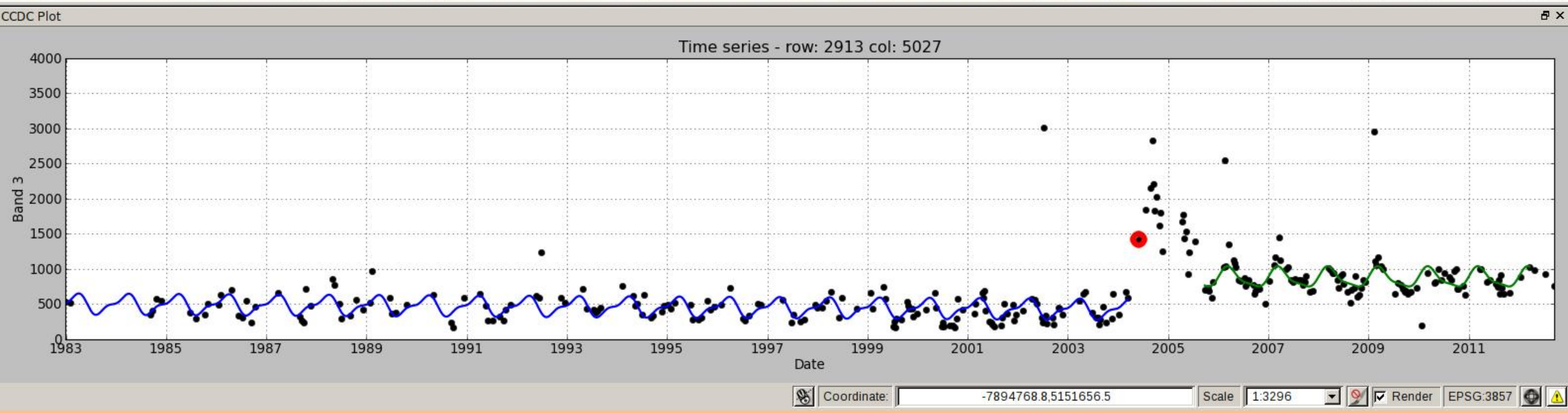
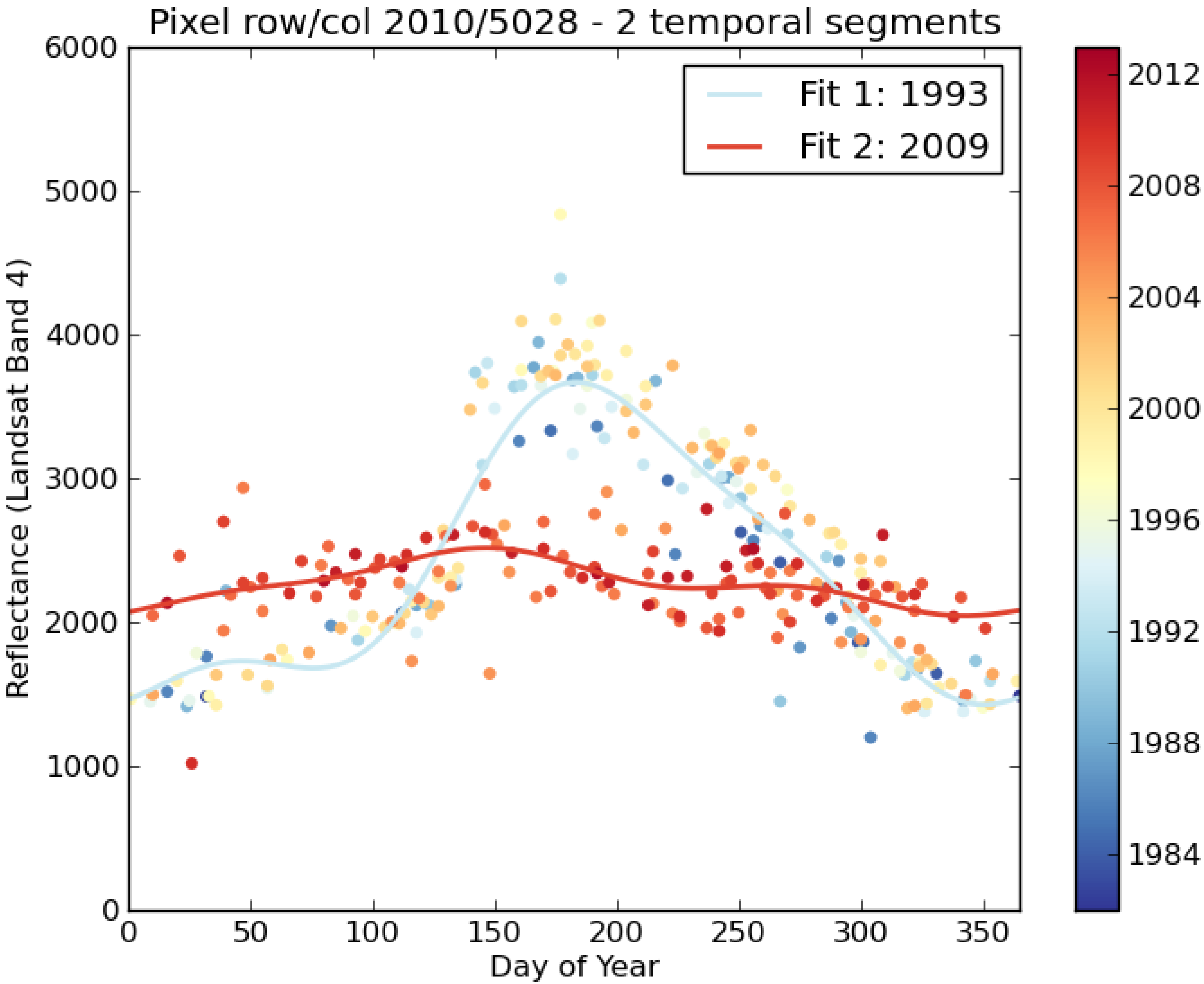


Image: Google Earth



Pixel row/col 2010/5028 - 2 temporal segments
Fit 1: 1993
Fit 2: 2009
Reflectance (Landsat Band 4)
Day of Year
0
1000
2000
3000
4000
5000
6000
0
50
100
150
200
250
300
350
2012
2008
2004
2000
1996
1992
1988
1984

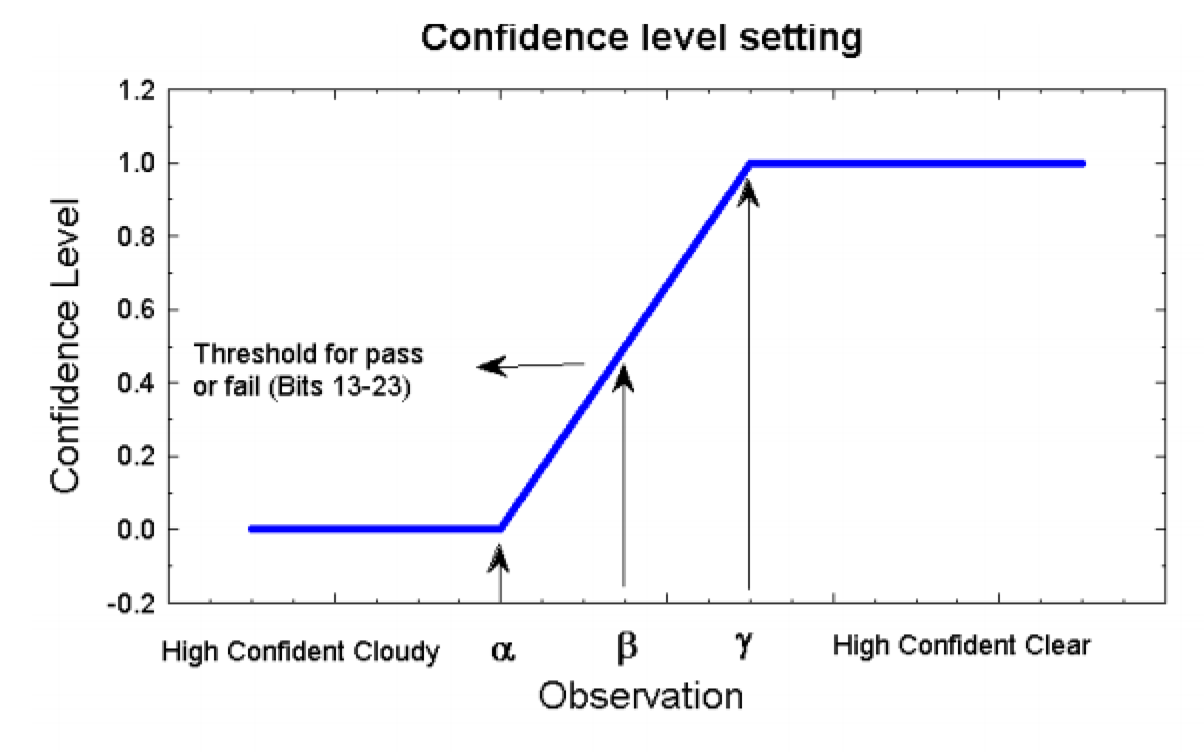
New Cloud/Cloud Shadow/Snow algorithm for Landsat 8 (Fmask)

- The cirrus band is used to compute a cirrus cloud probability that is combined with the previous Fmask probability mask.
- The only differences are in the potential cloud mask.
- (We can make a beta version available online if people are interested)

Cirrus Cloud Probability Calculation

α (Confident Clear)	γ (Confident Cloud)
0.00 (0.03)	0.01 (0.04)

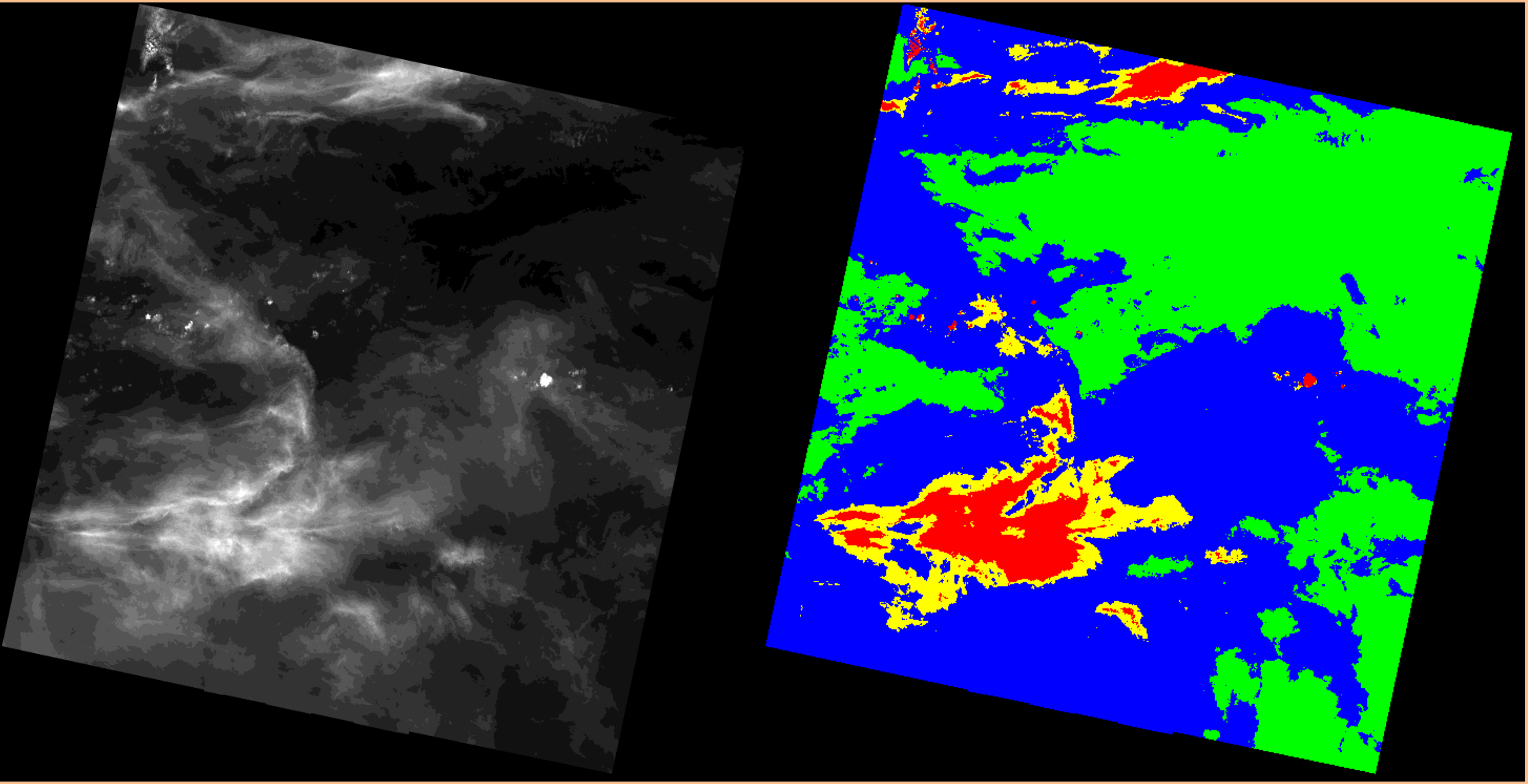
The numbers in the parenthesis are MODIS test thresholds for land pixels. The number in red are new Fmask test threshold for all pixels. The MODIS high thresholds are mainly due to the cross-talking issues in the narrow bands.



From Ackerman et al., ATBD, 2010

Thresholds for Cirrus clouds

Cirrus band TOA reflectance: 0-0.01, 0.01-0.03, 0.03-0.04, 0.04-1



Landsat 8 image at Path 33 Row 61 (Amazon) acquired in October 5th 2013

Potential Cloud Layer

- Step 1: Retrieving Potential Cloud Pixels (PCP)

- **Inputs for PCP computing:**
- *Basic tests (Temperature, Band 7 ref, NDVI, and NDSI)*
- *Whiteness*
- *0.47 vs. 0.66*
- *Band 4/Band 5*
- *Water test*
- *Cirrus cloud test*

Potential Cloud Layer

- Step 2: Build Cloud probability mask (land)

- ***1. Temperature probability:*** *Using non-PCP to calculate land surface temperature range (TempLow,TempHigh) and calculate the normalized Temperature probability for cloud (Temperature_prob).*
- ***2. Variation probability:*** *Choosing the largest value among NDSI, NDVI, and whiteness to calculate the spectral variation probability for cloud (Variation_prob).*

- *Cloud_prob=Temperature_prob*(1-variation_prob) + Cirrus_prob*

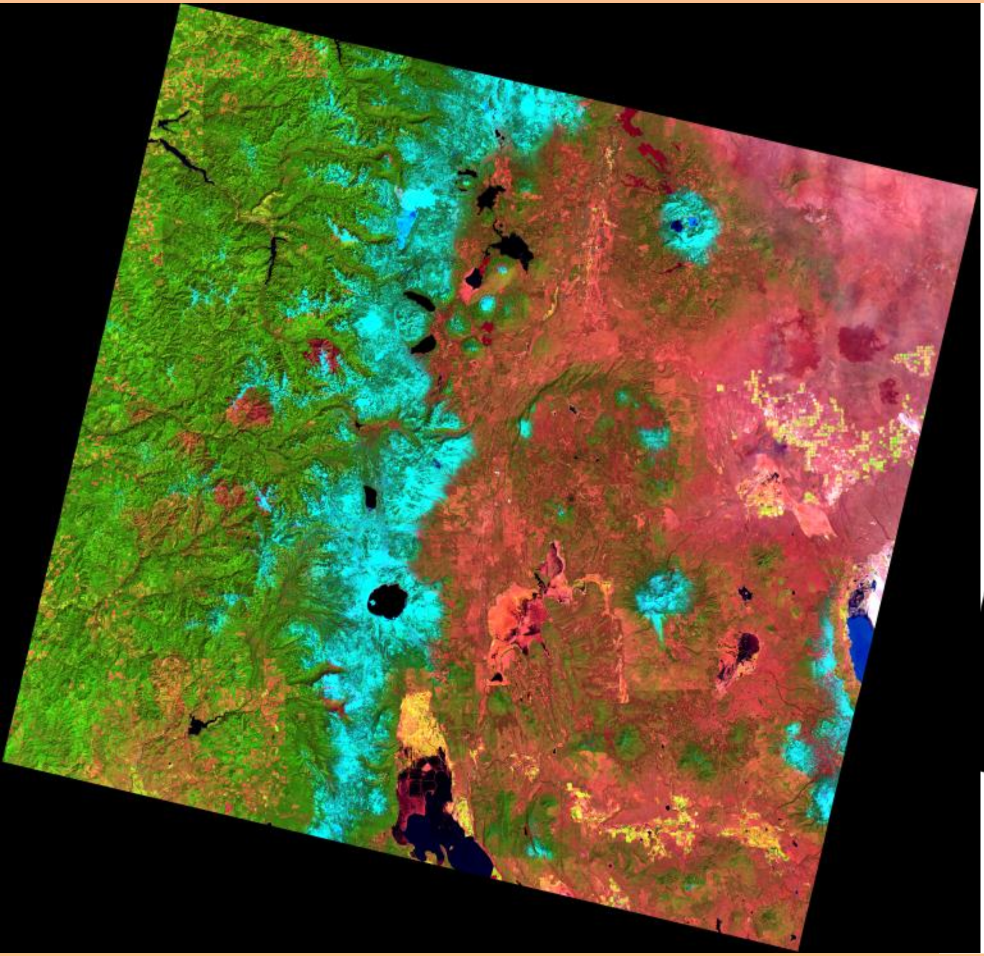
Potential Cloud Layer

- Step 2: Build Cloud probability mask (water)

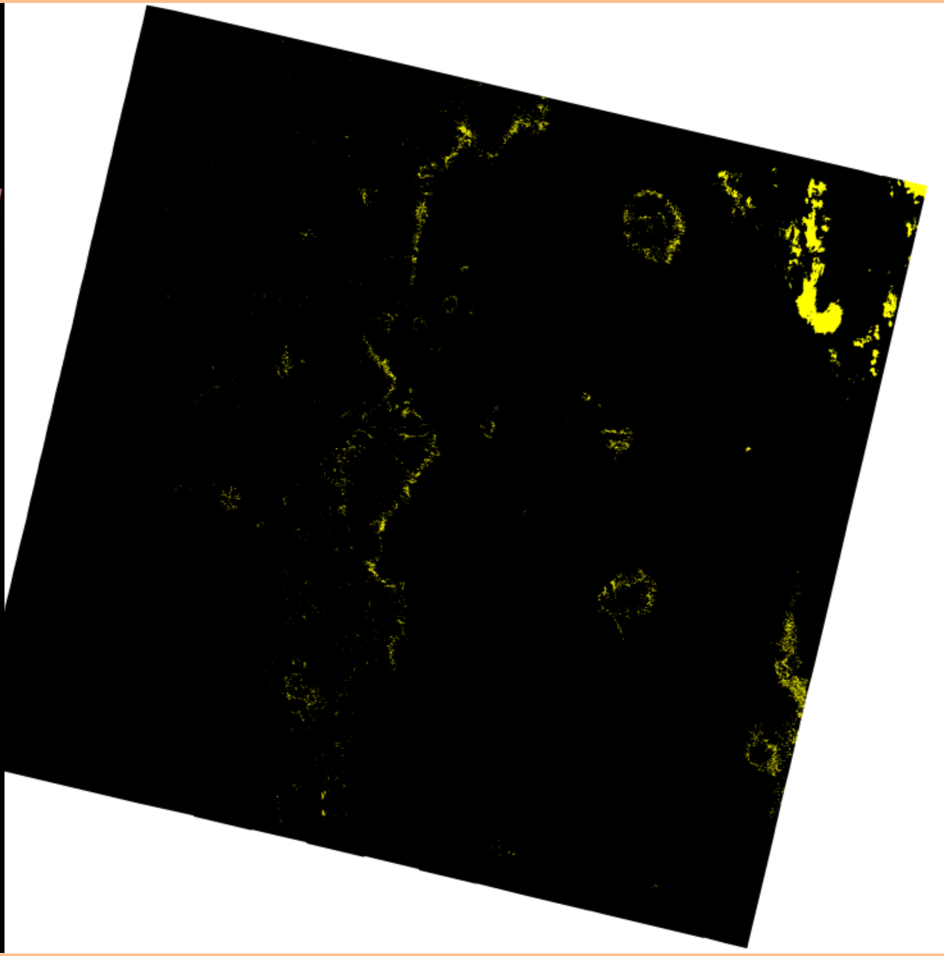
- ***1. Temperature probability:*** *Using non-PCP to calculate water surface temperature and calculate the normalized Temperature probability for cloud (Temperature_prob).*
- ***2. Brightness probability:*** *Using normalized Band 5 reflectance to compute cloud probability (Brightness_prob).*

- *wCloud_prob=Temperature_prob*Brightness_prob + Cirrus_prob*

SWIR, NIR, and Red composite

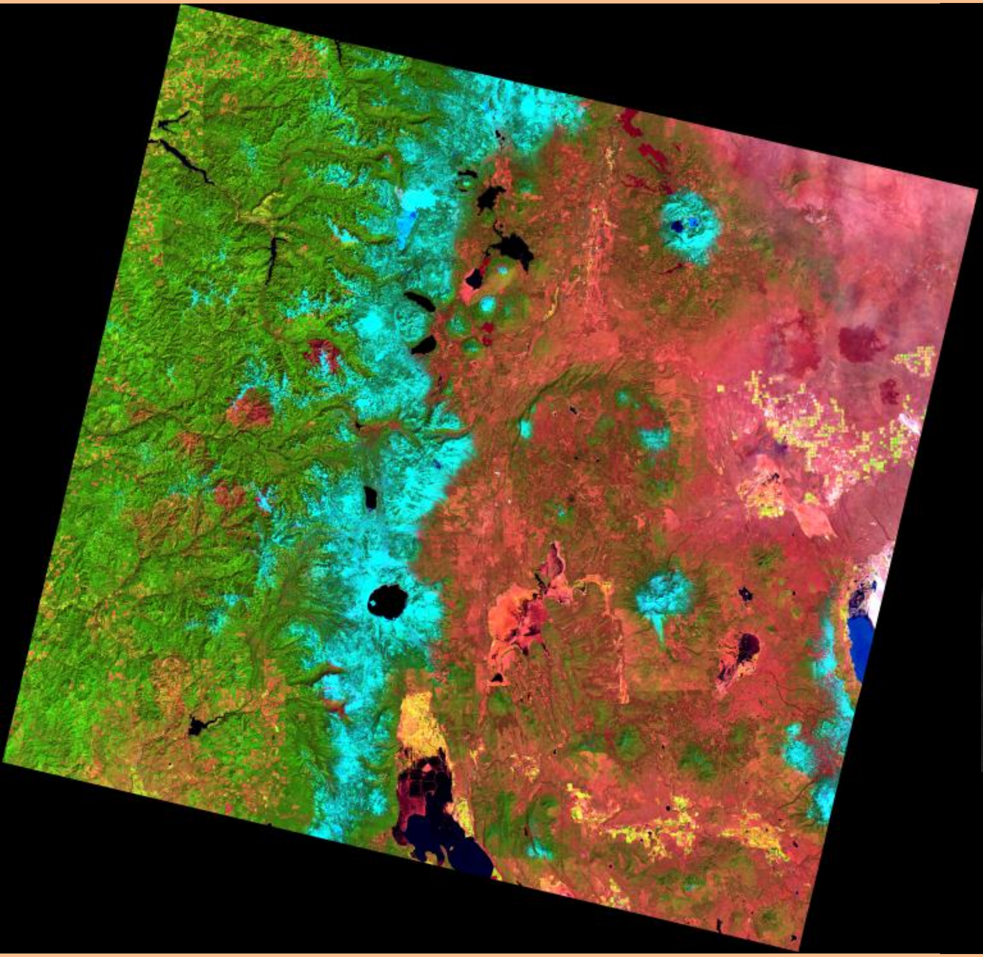


Old Fmask results

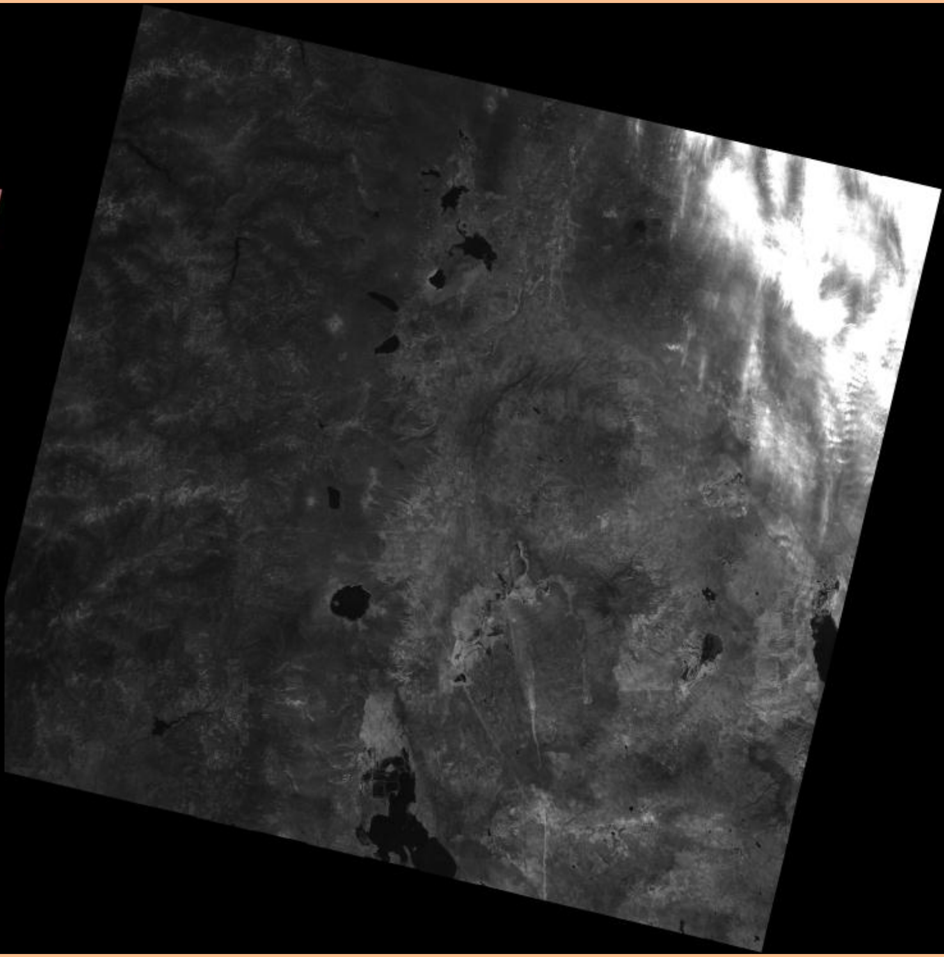


Landsat 8 image for Path 45 Row 30 (Oregon) acquired on April 23th 2013

SWIR, NIR, and Red composite

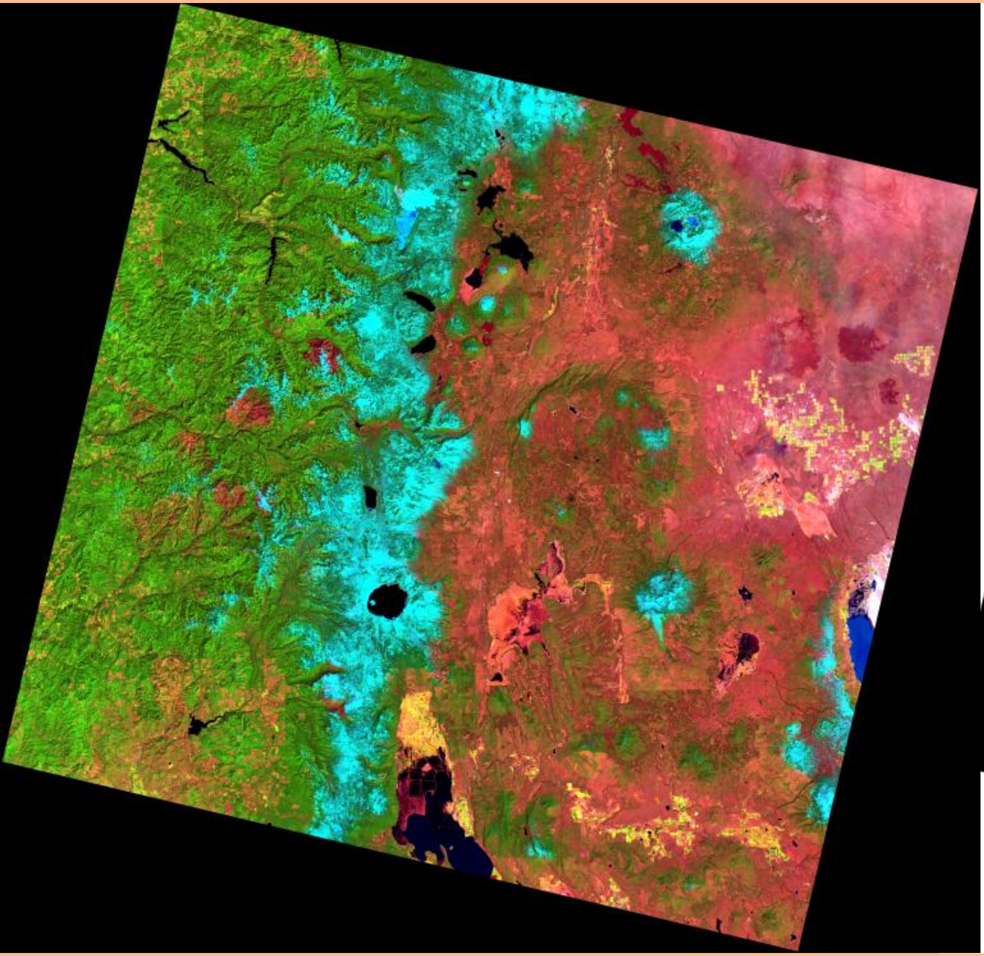


The new Cirrus band

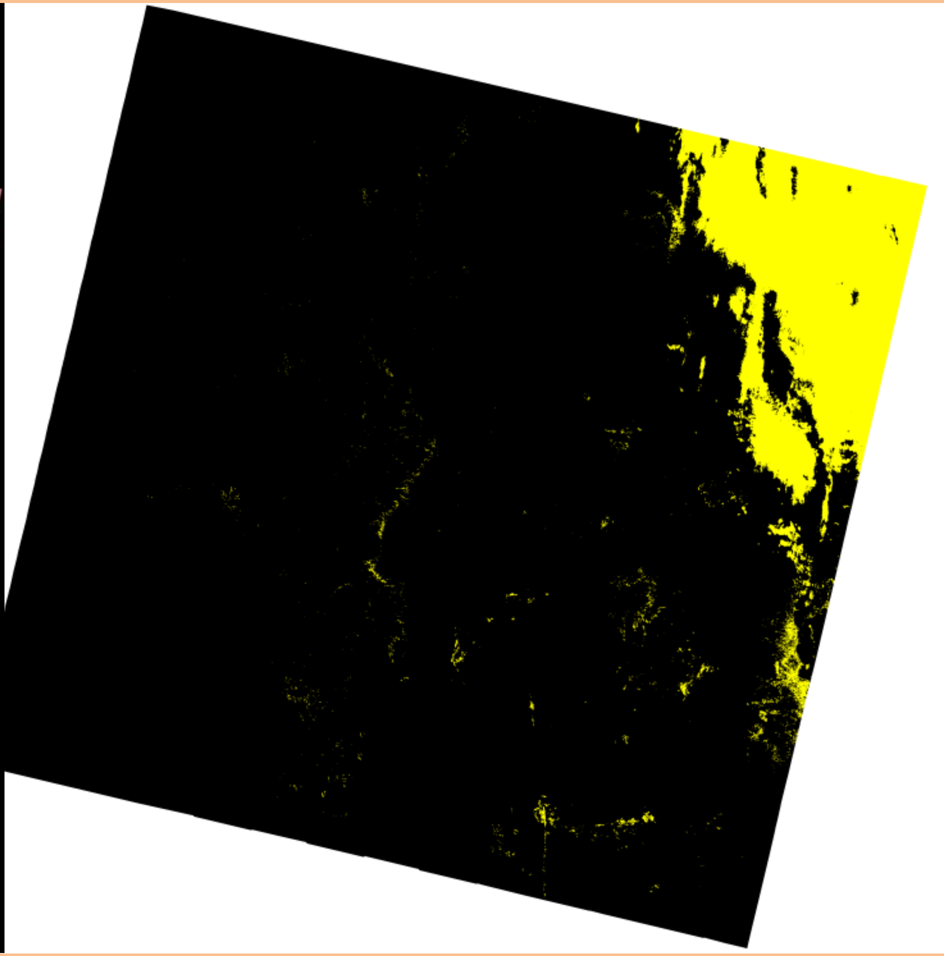


Landsat 8 image at Path 45 Row 30 (Oregon) acquired in April 23th 2013

SWIR, NIR, and Red composite



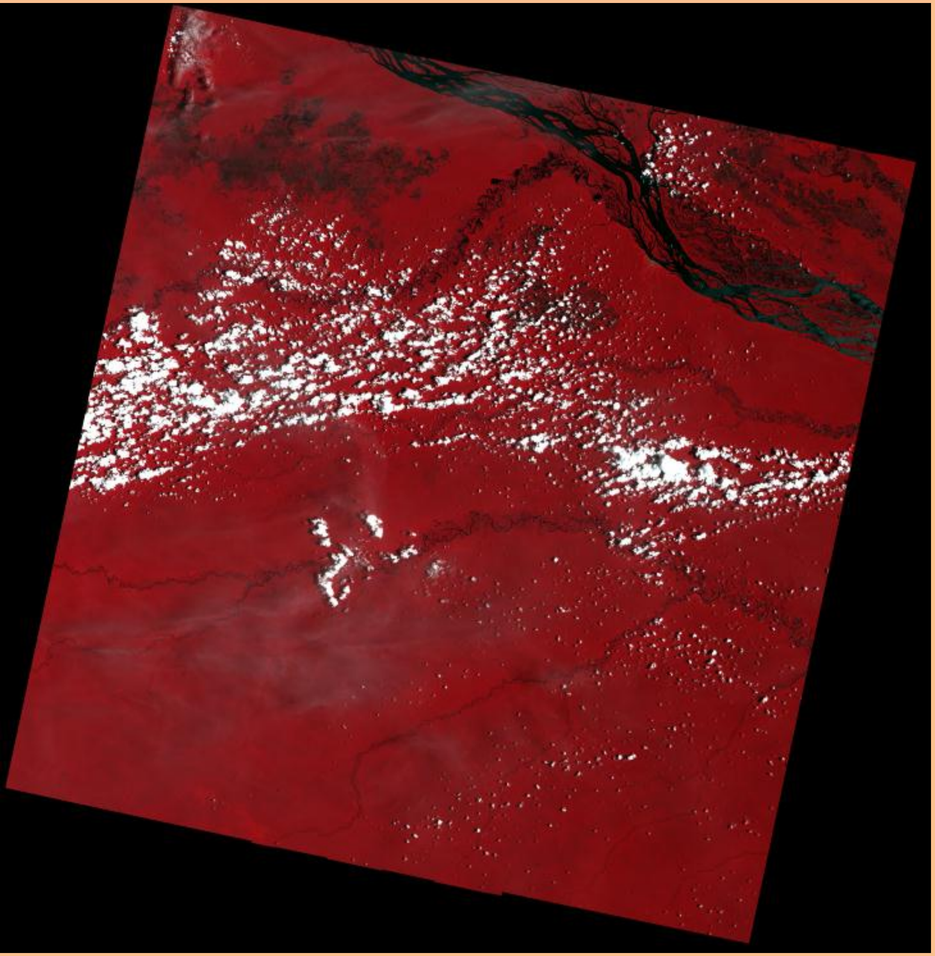
New Fmask results

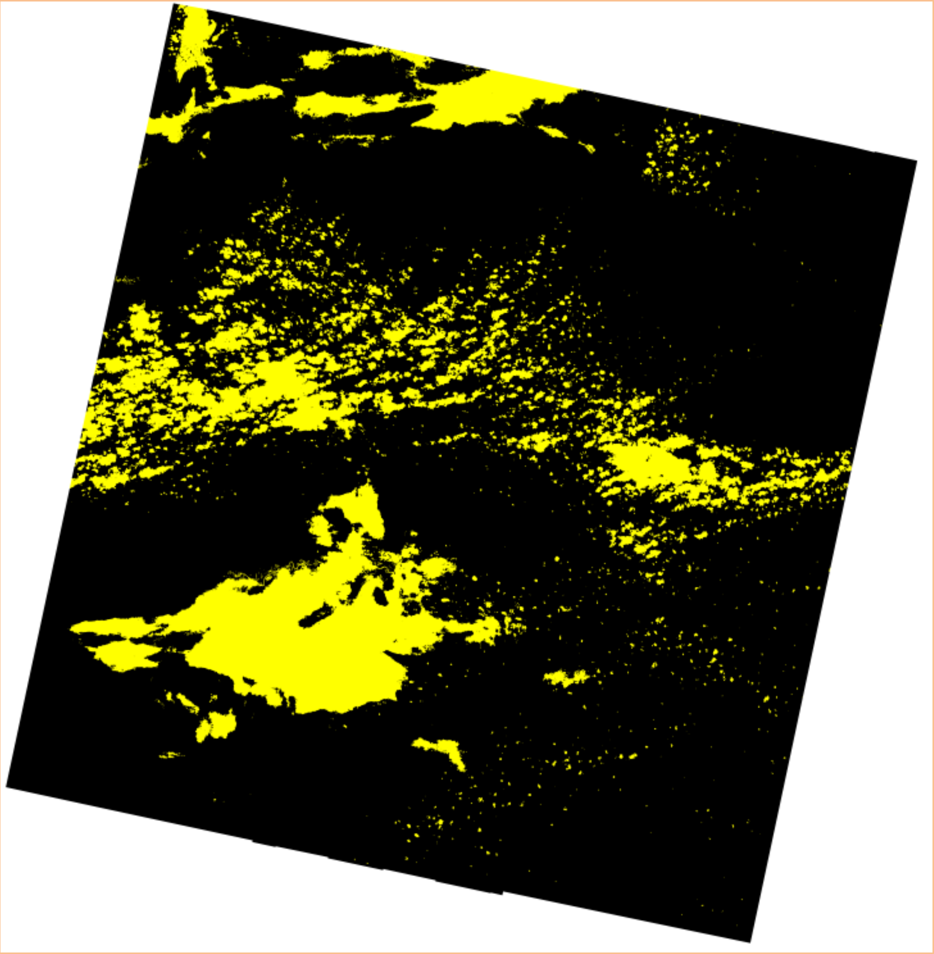


Landsat 8 image at Path 45 Row 30 (Oregon) acquired in April 23th 2013

NIR, Red, and Green composite

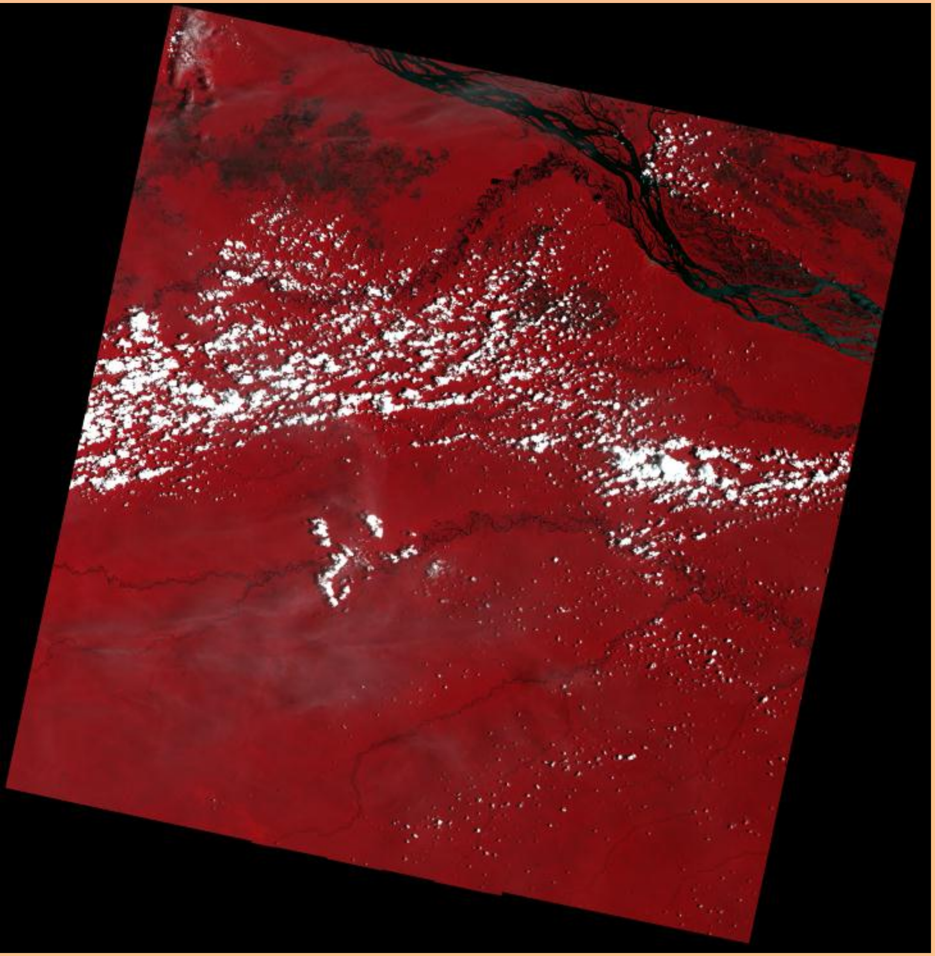
Old Fmask results



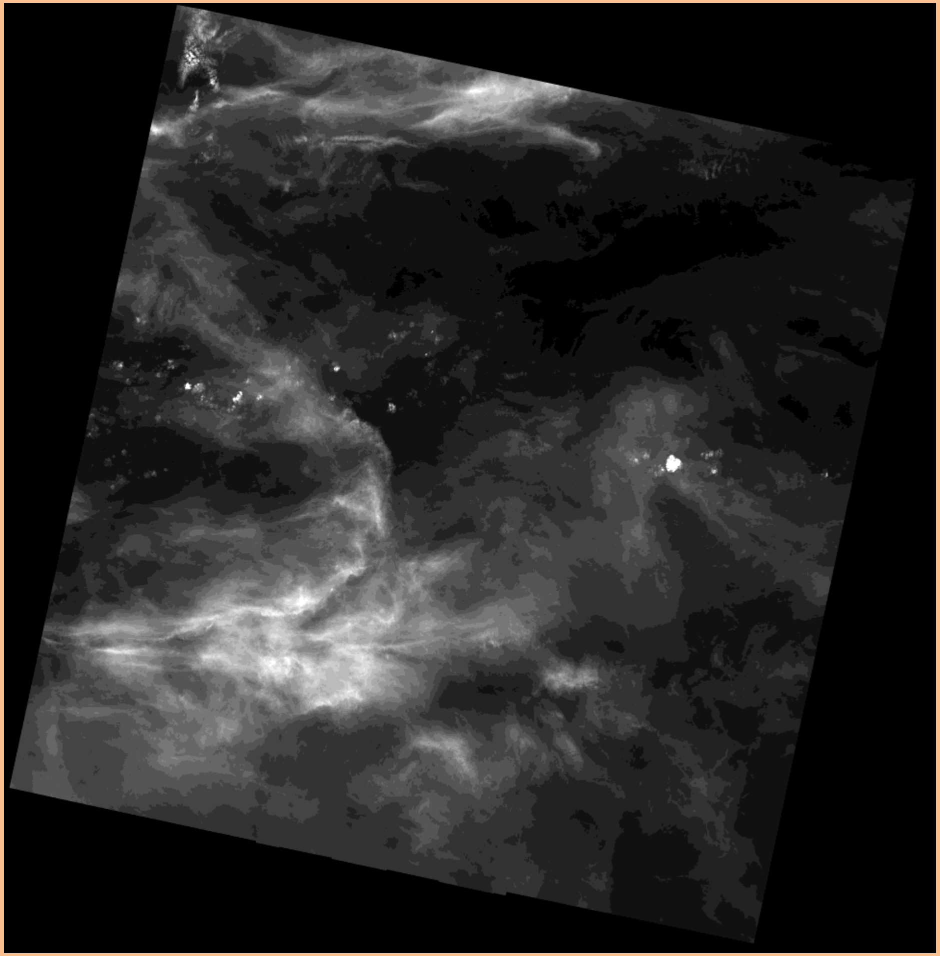


Landsat 8 image for Path 33 Row 61 (Amazon) acquired on October 5th 2013

NIR, Red, and Green composite



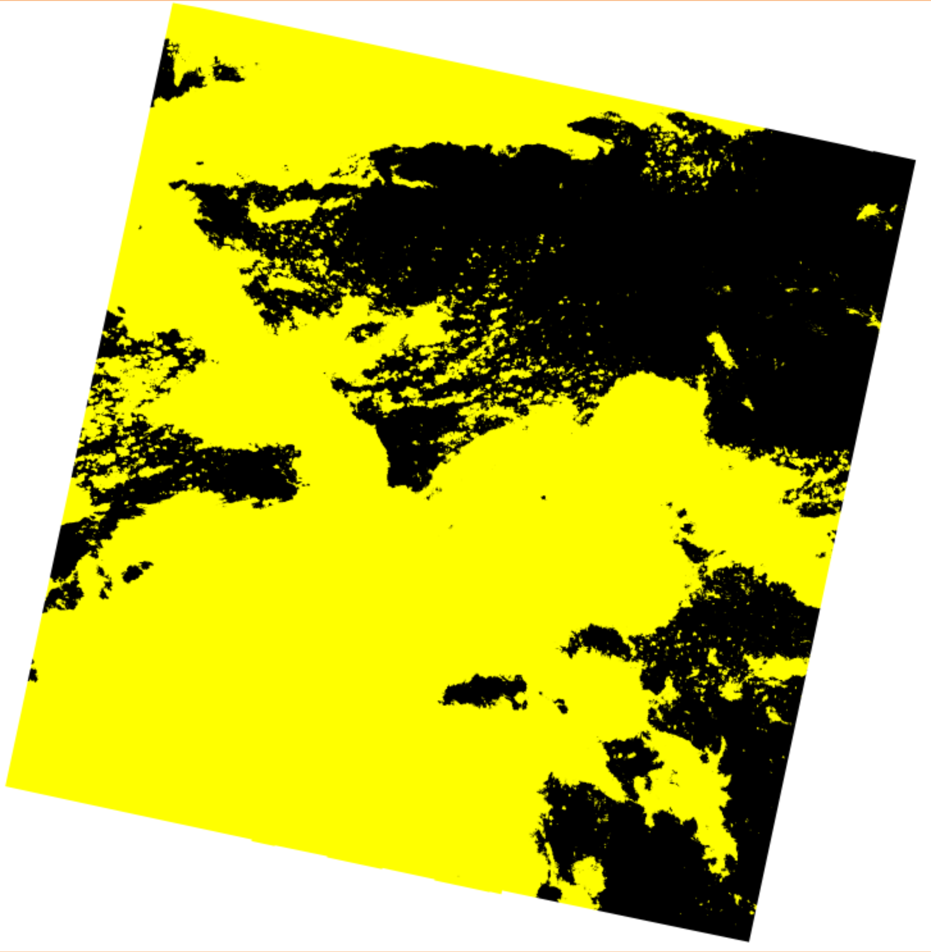
The new Cirrus band

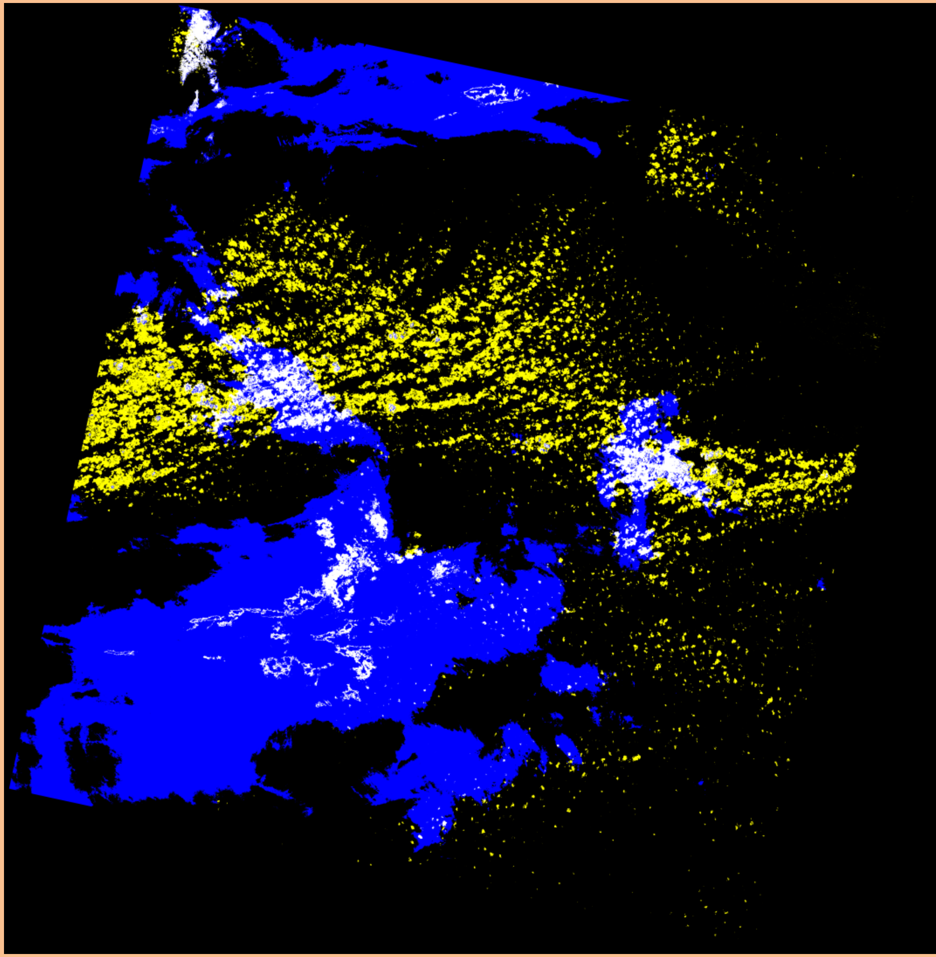


Landsat 8 image at Path 33 Row 61 (Amazon) acquired in October 5th 2013

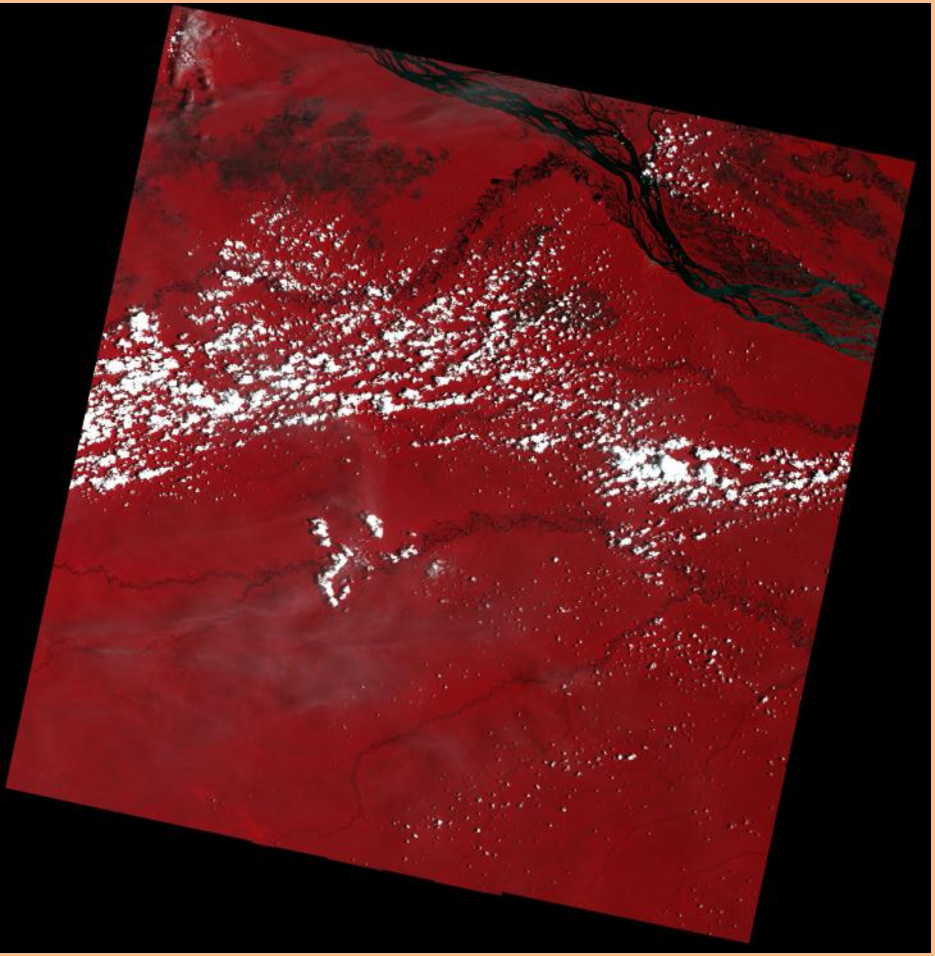
The new Fmask
Yellow (cloud)

Cirrus and cloud mask from QA
Yellow (cloud) blue (cirrus)

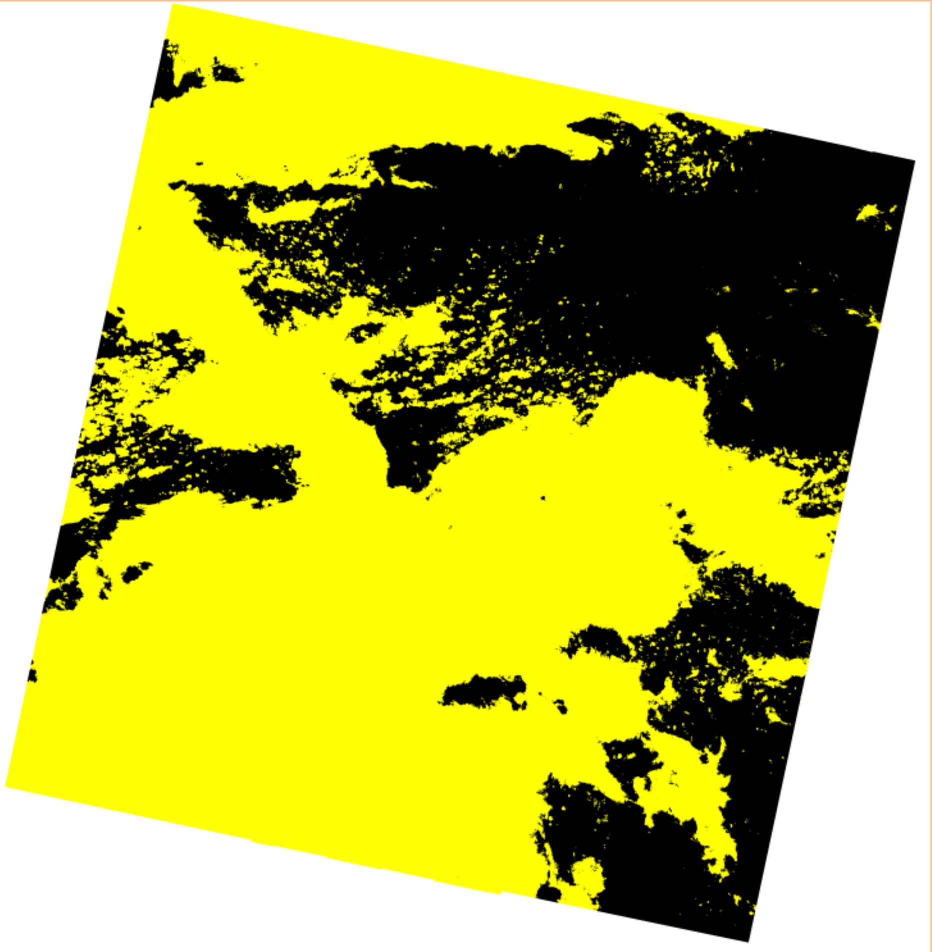




NIR, Red, and Green composite

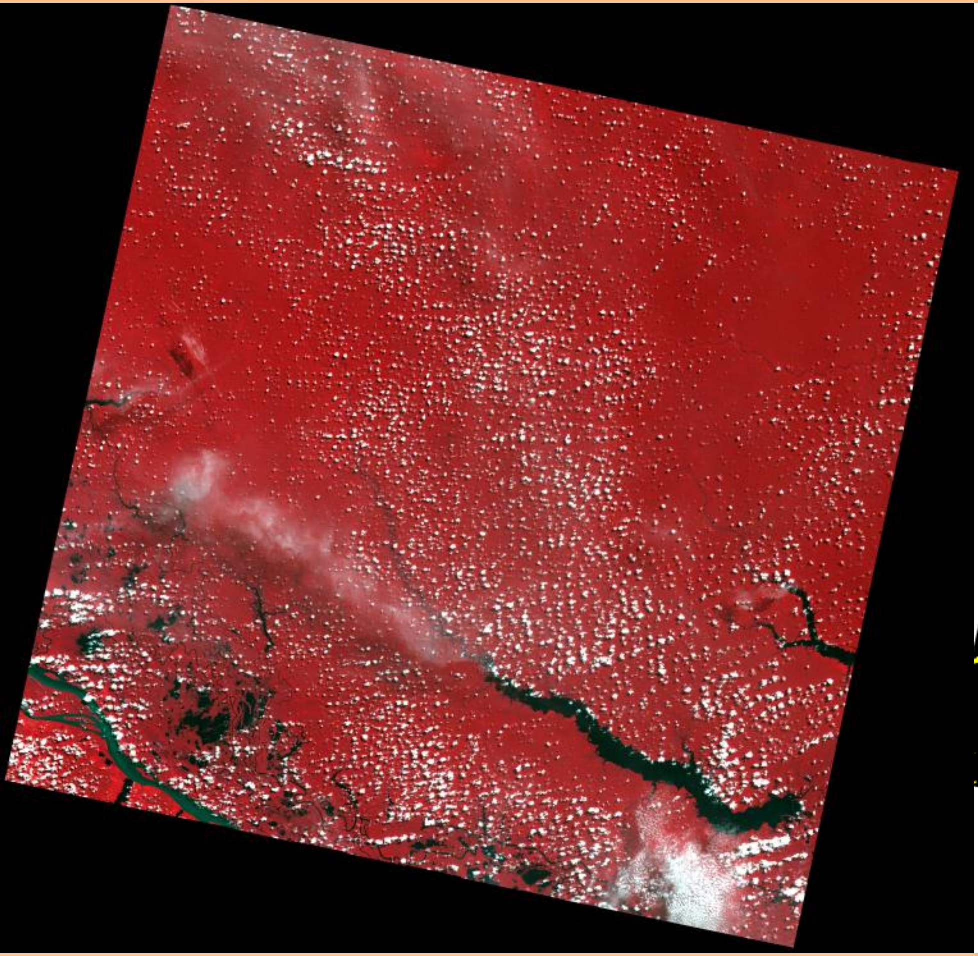


New Fmask results

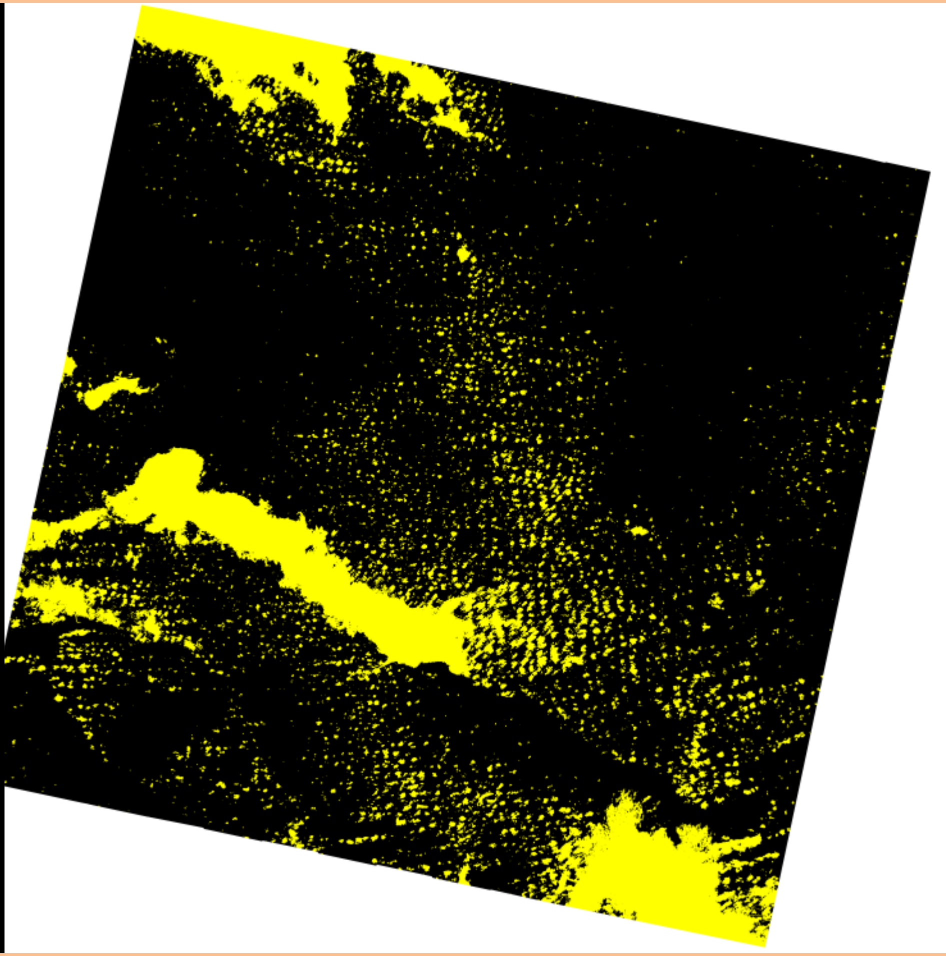


Landsat 8 image at Path 33 Row 61 (Amazon) acquired in October 5th 2013

NIR, Red, and Green composite

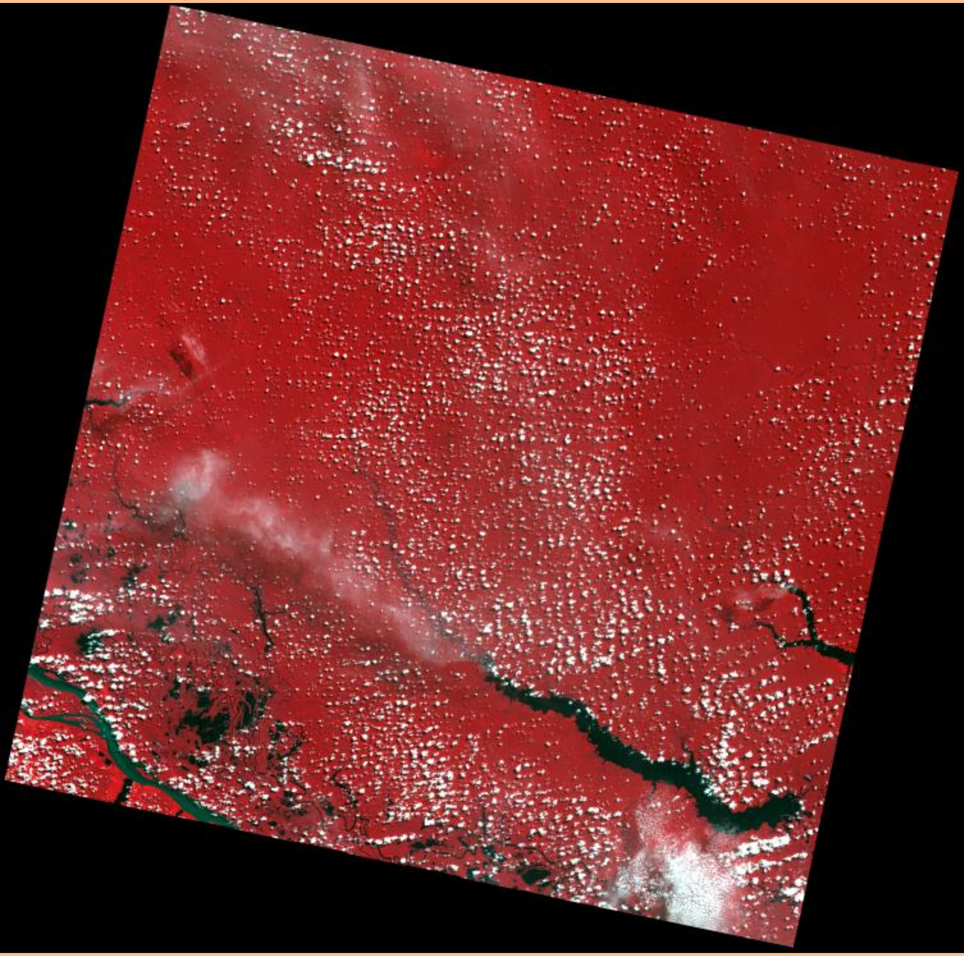


Old Fmask results

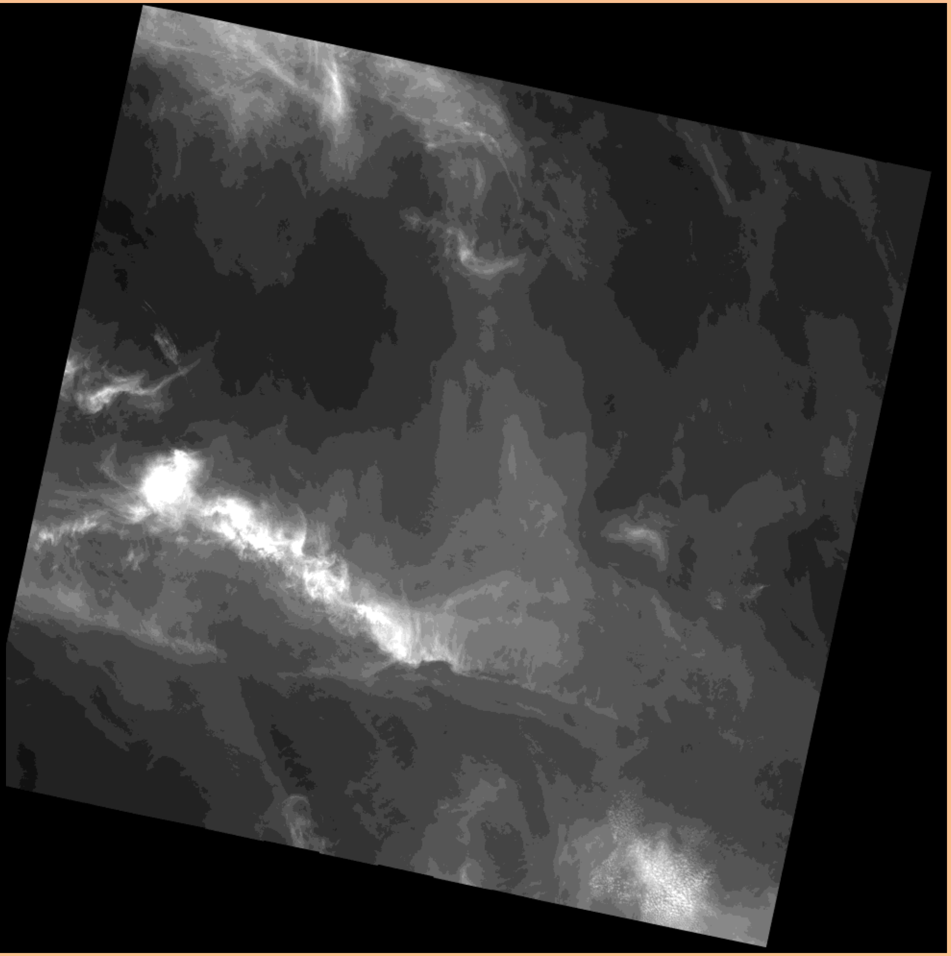


Landsat 8 image at Path 33 Row 62 (Amazon) acquired in May 30th 2013

NIR, Red, and Green composite



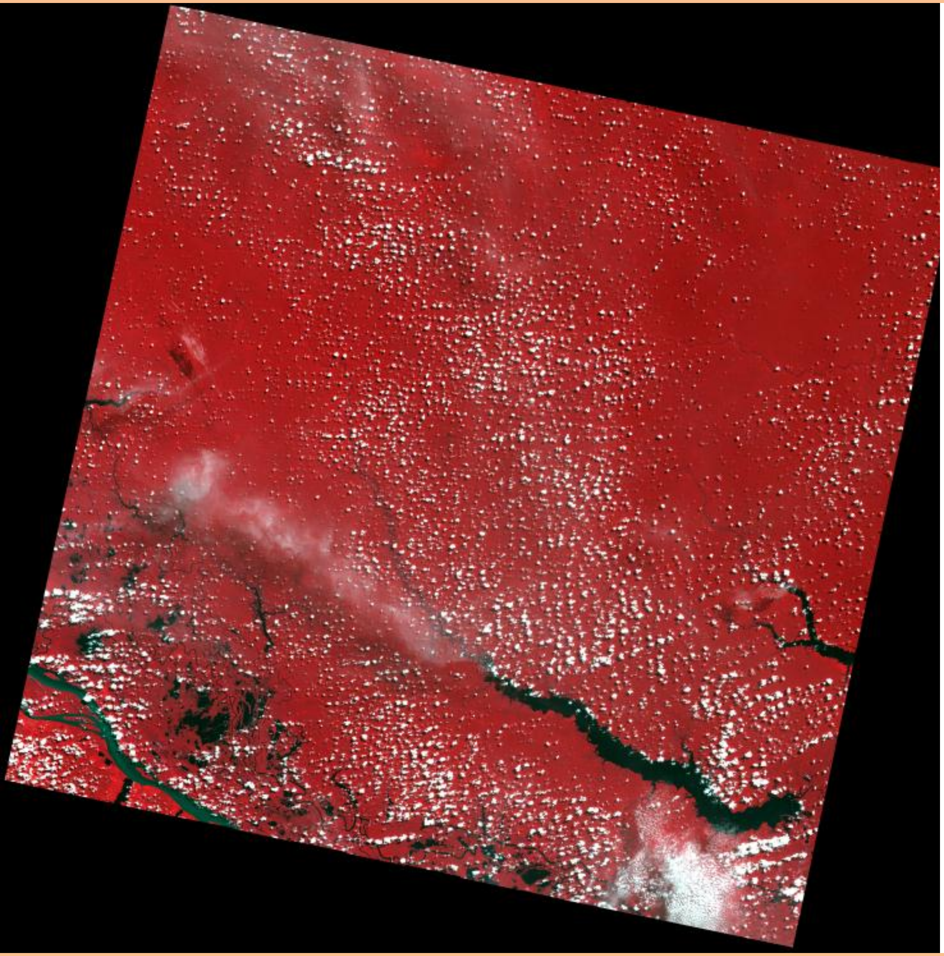
The new Cirrus band

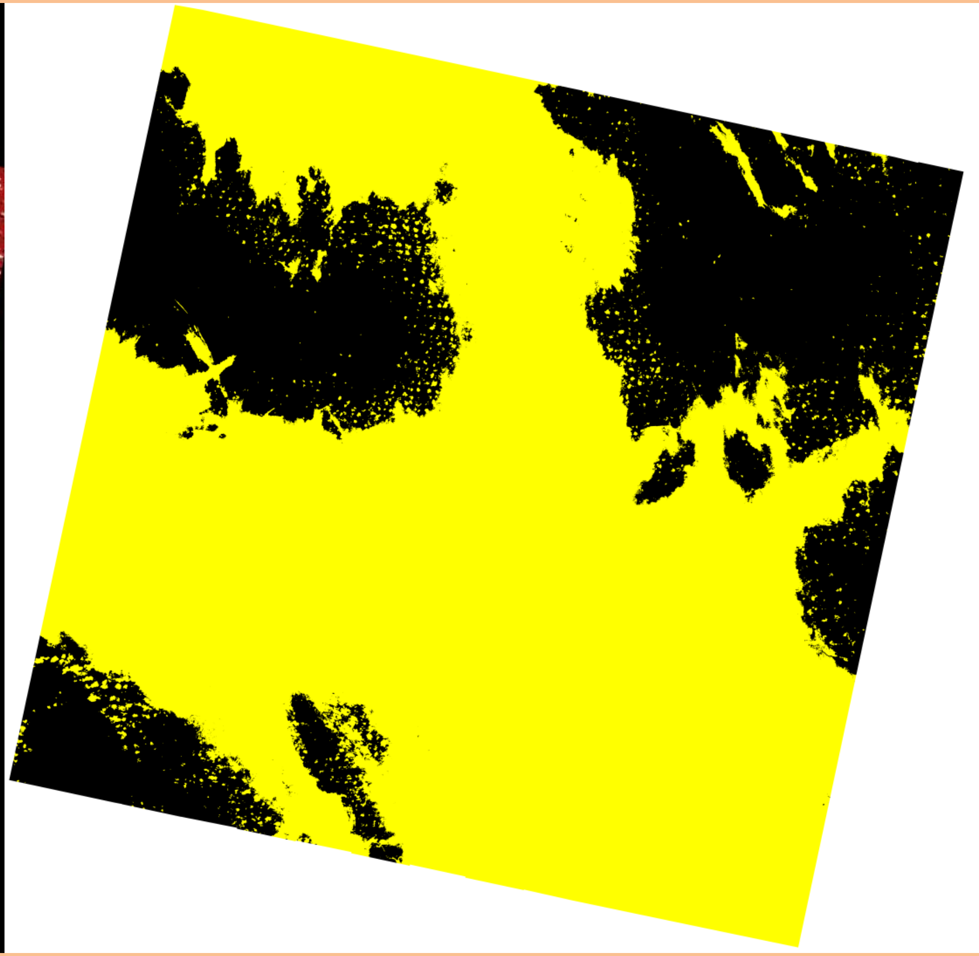


Landsat 8 image at Path 33 Row 62 (Amazon) acquired in May 30th 2013

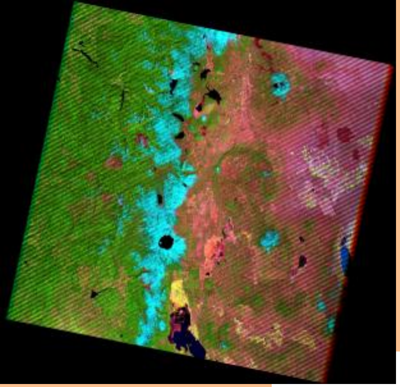
NIR, Red, and Green composite

New Fmask results

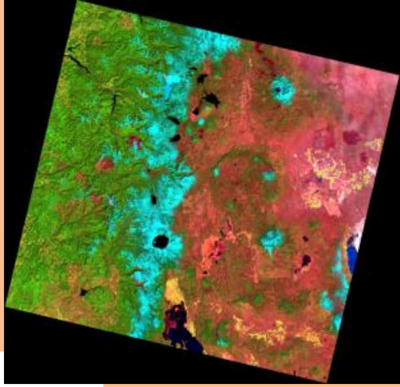




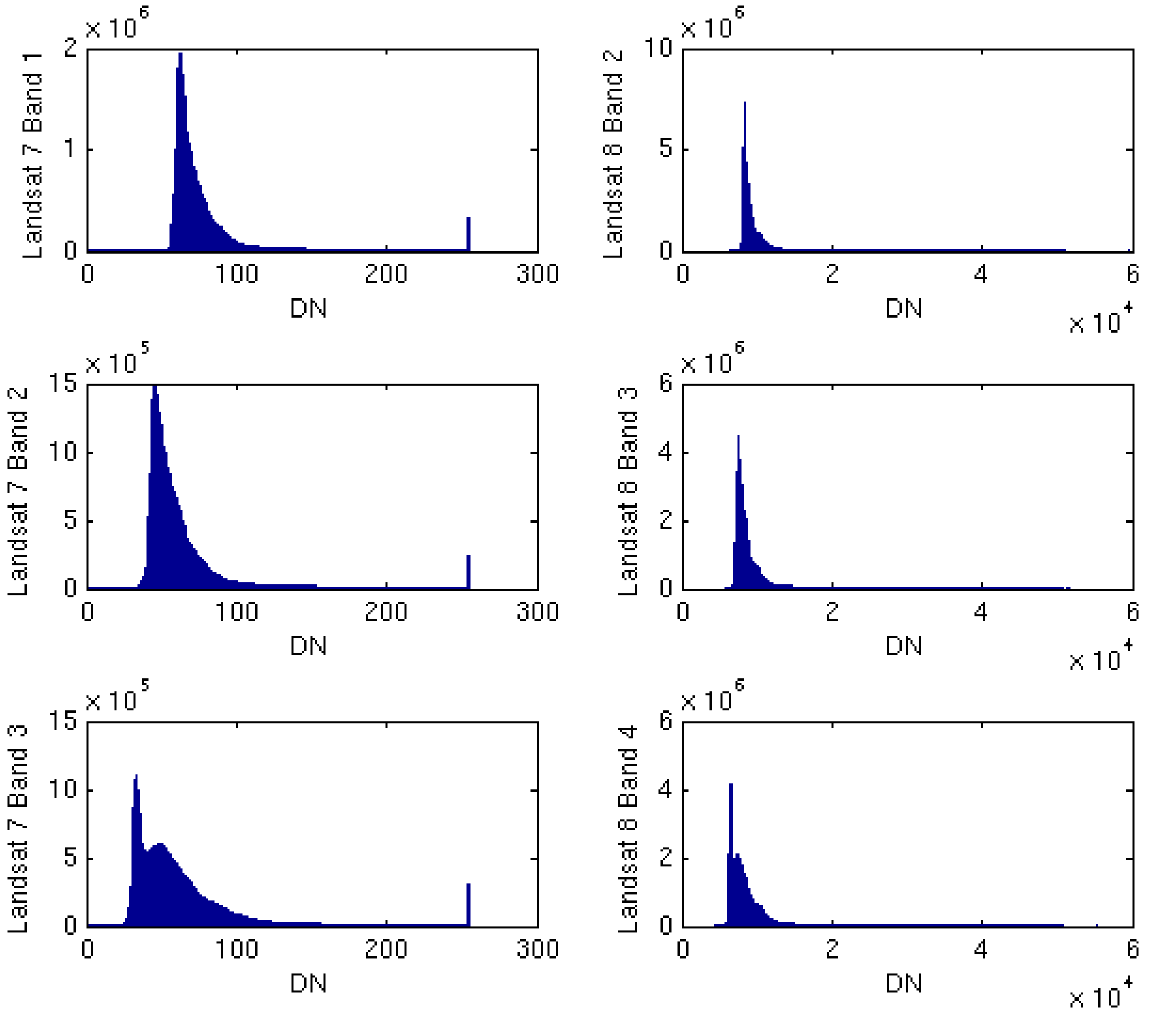
Landsat 8 image at Path 33 Row 62 (Amazon) acquired in May 30th 2013



No saturation
even for the blue Band!



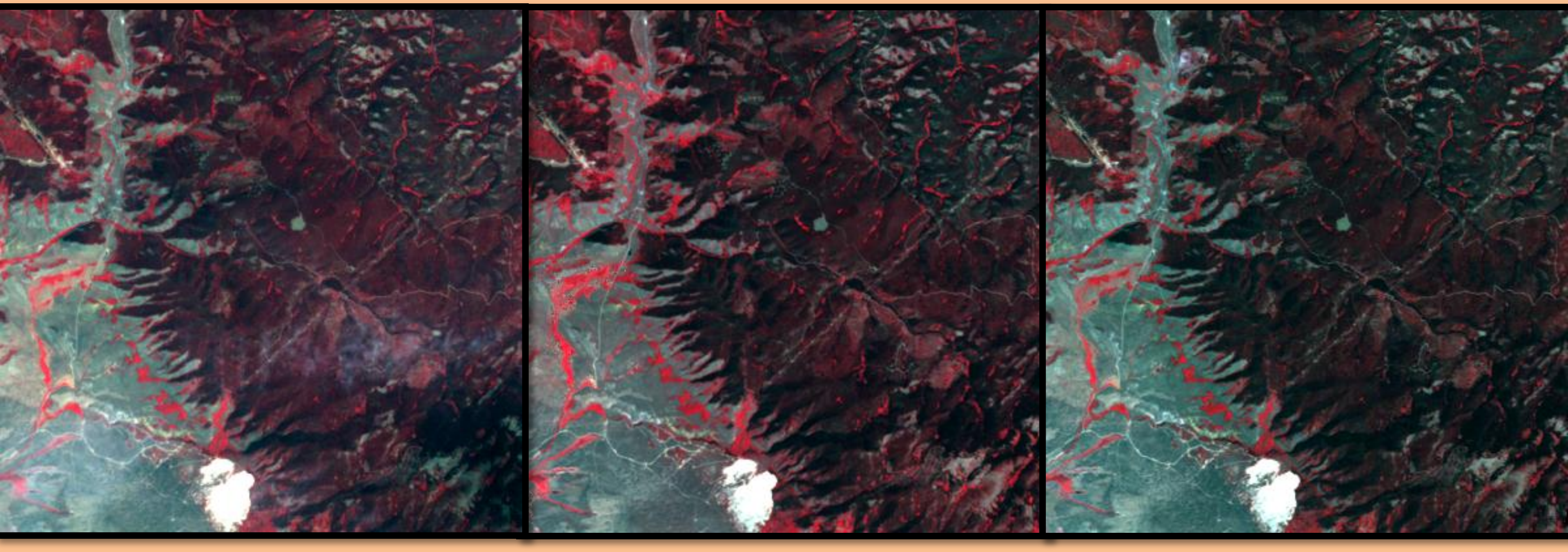
SWIR, NIR, and Red composite at Oregon from Landsat 7 in May 1st , 2013



SWIR, NIR, and Red composite at Oregon from Landsat 8 in April 23rd , 2013

“Synthetic” data, or “model-based composite”, or ????

Path 35 Row 32 (Colorado) NIR, Red, and Green composite



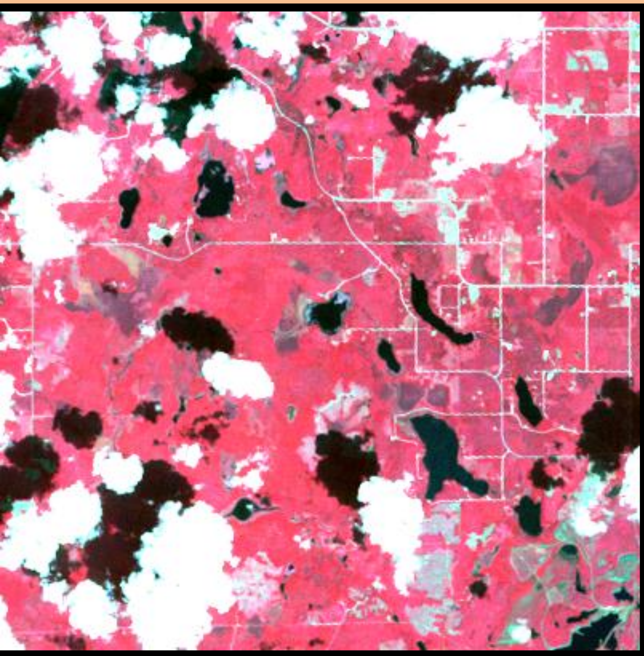
August 1st
Landsat 7

August 6th 2002
Synthetic image

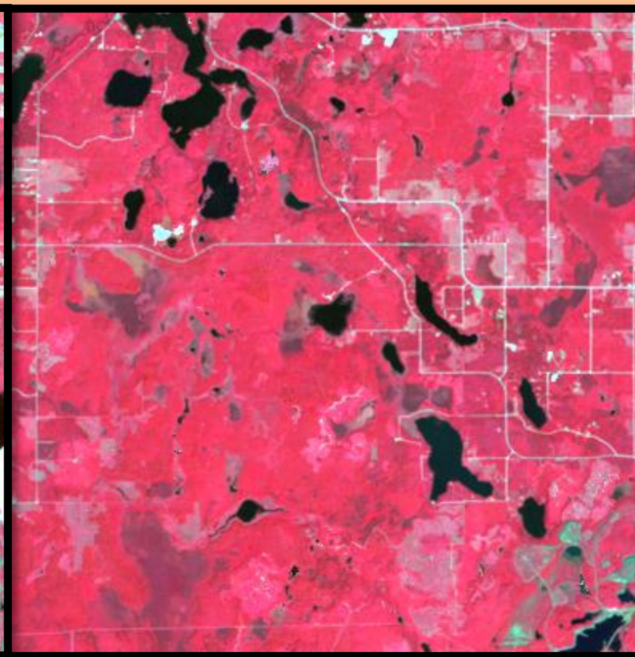
August 9th 2002
Landsat 5

Synthetic data

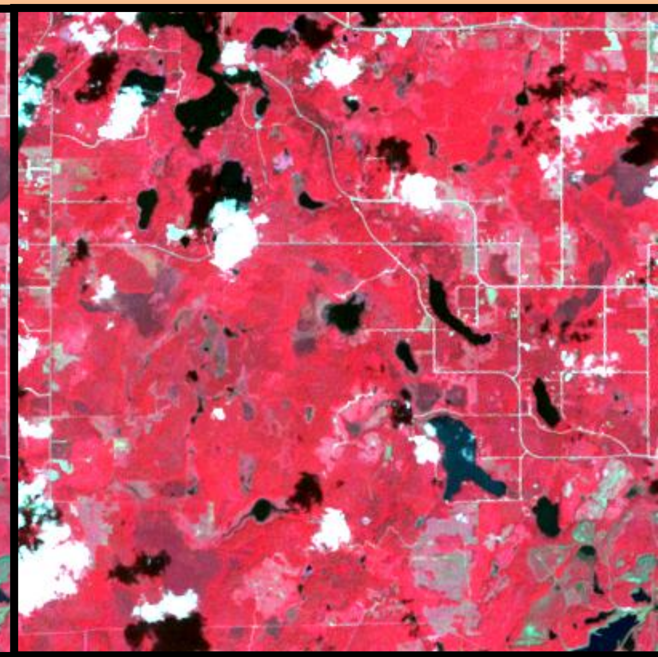
Path 27 Row 27 (Maine) NIR, Red, and Green composite



July 13^{th} 2001
Landsat 5



August 6^{th} 2001
Synthetic image



August 6^{th} 2001
Landsat 7

Comparison of land cover classifications using Landsat 8 and Landsat 7 data (Underflight Data)

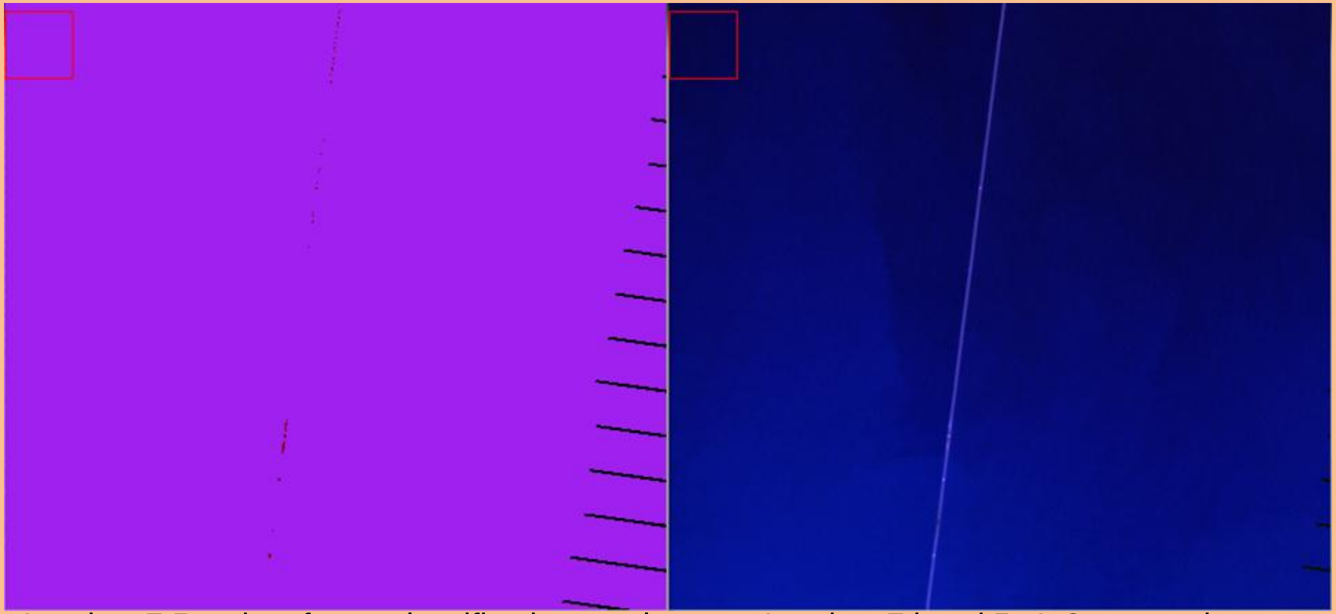
1. Data: p22 r39
2. Date: 03/29/2013
3. Location: Southern Louisiana
4. Size: 3000 X 3000 pixels
5. 0% cloud coverage
6. Bands used
   - Landsat 7: 1, 2, 3, 4, 5, and 7
   - Landsat 8: 2, 3, 4, 5, 6, and 7
7. Classification algorithm: Random Forest

Classification Comparison (L7 and L8)

- At least 3 reasons to expect improvements
  - Improved radiometric resolution (improved signal to noise)
  - Better detection of thin clouds
  - New spectral band (and possibly the improvements in the heritage bands)
- We've tested the first case – by only using the heritage bands from L8 in comparisons with L7 from coincident images without clouds

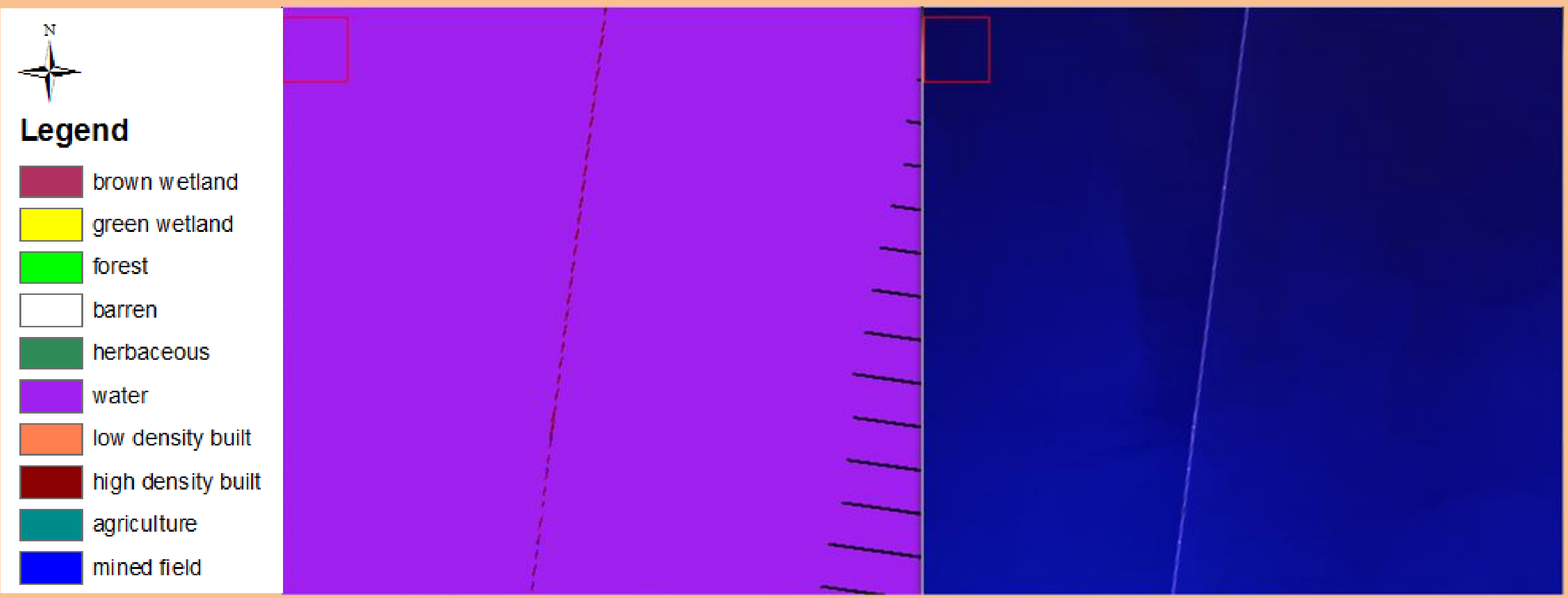
Results (Louisiana scene)

- 86% of pixels classified the same -- and those pixels are correctly classified 88% of the time
- Of the pixels classified differently, the L8 answer is correct 70% of the time and L7 answer only 17.2% of the time
- There appears to be less of the “salt and pepper effect” (high frequency noise) in the classification results of L8 (not yet addressed quantitatively)



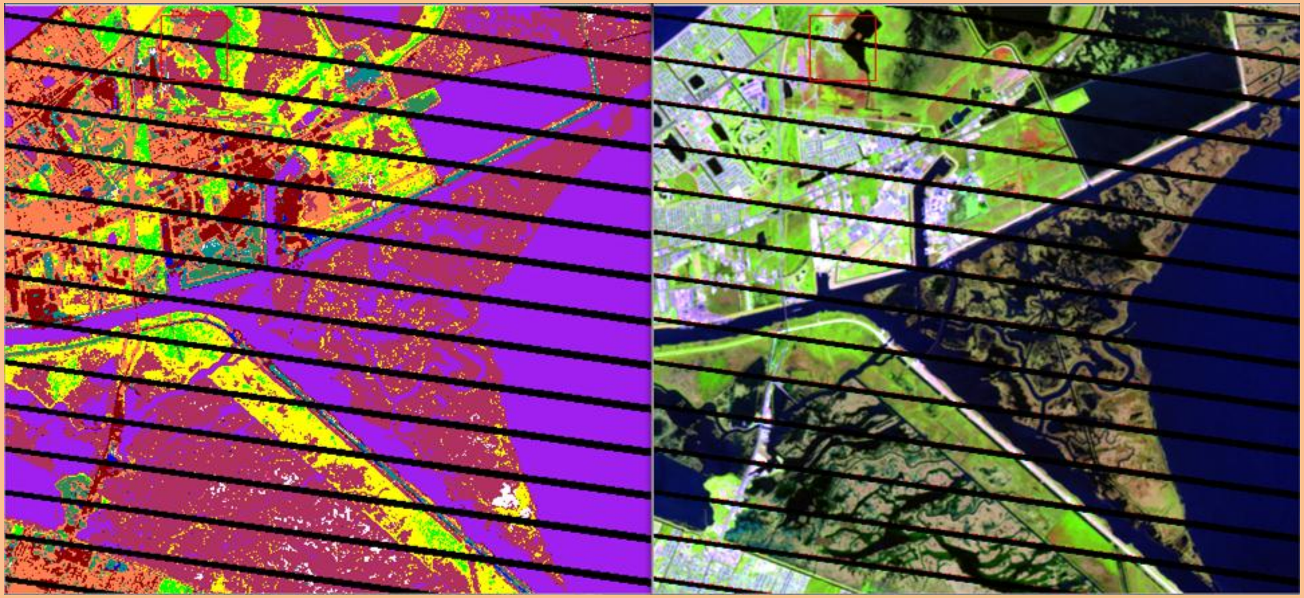
Landsat 7 Random forest classification results Landsat 7 band 5, 4, 3 composite

(400 X 400 pixels)

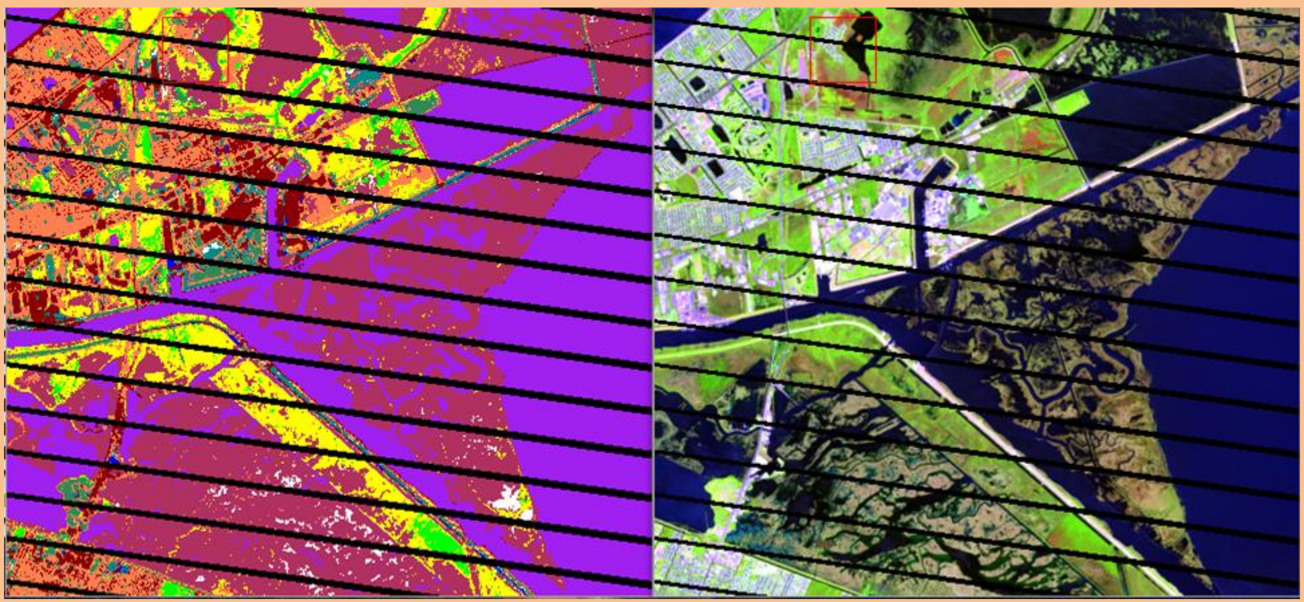


Landsat 8 Random forest classification results Landsat 8 underfly band 6, 5, 4 composite

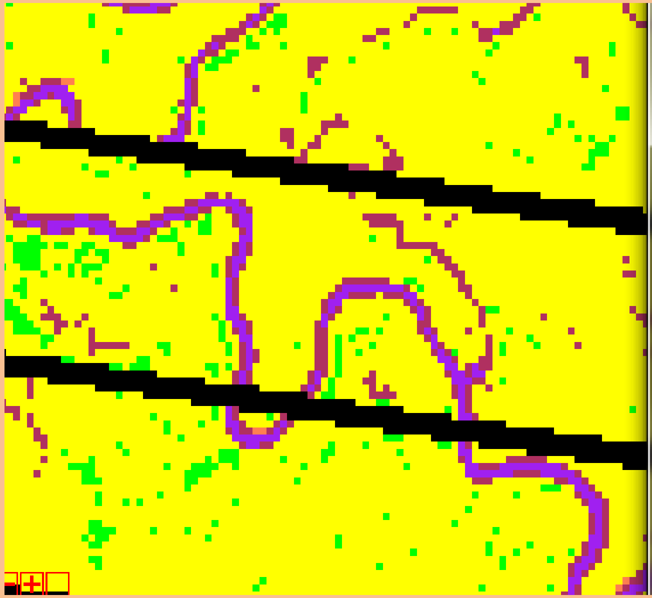
(400 X 400 pixels)

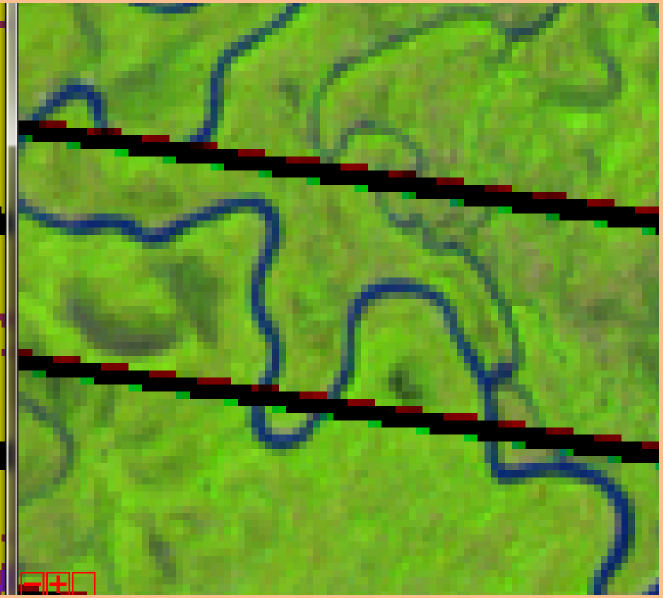


Landsat 7 Random forest classification results Landsat 7 band 5, 4, 3 composite
(400 X 400 pixels)

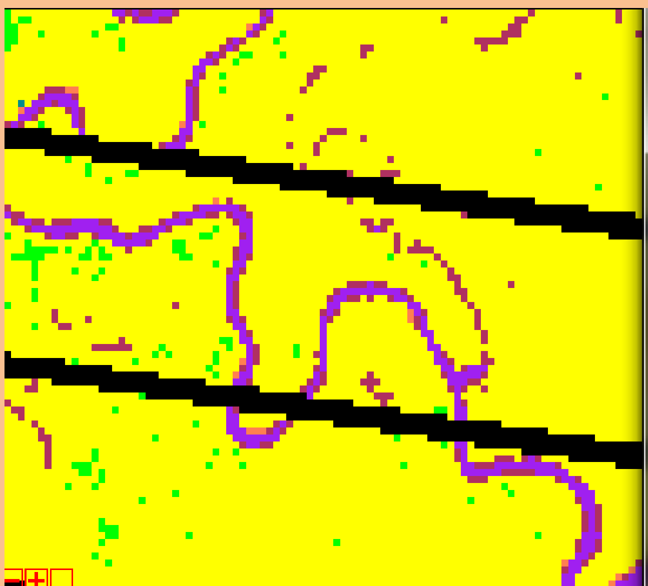


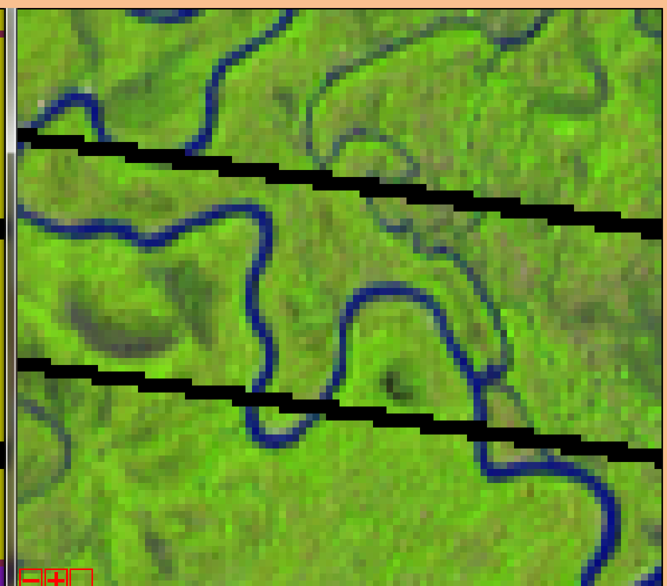
Landsat 8 Random forest classification results Landsat 8 underfly band 6, 5, 4 composite
(400 X 400 pixels)



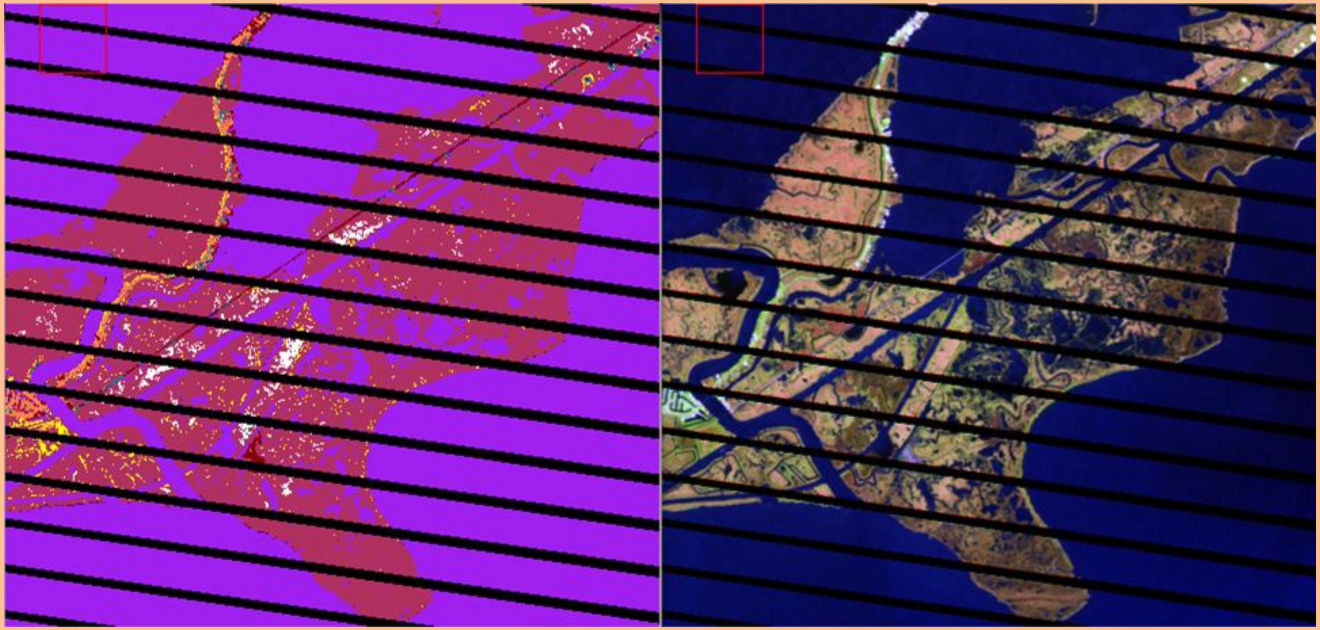


Landsat 7 Random forest classification results Landsat 7 band 5, 4, 3 composite
(87 X 87 pixels)





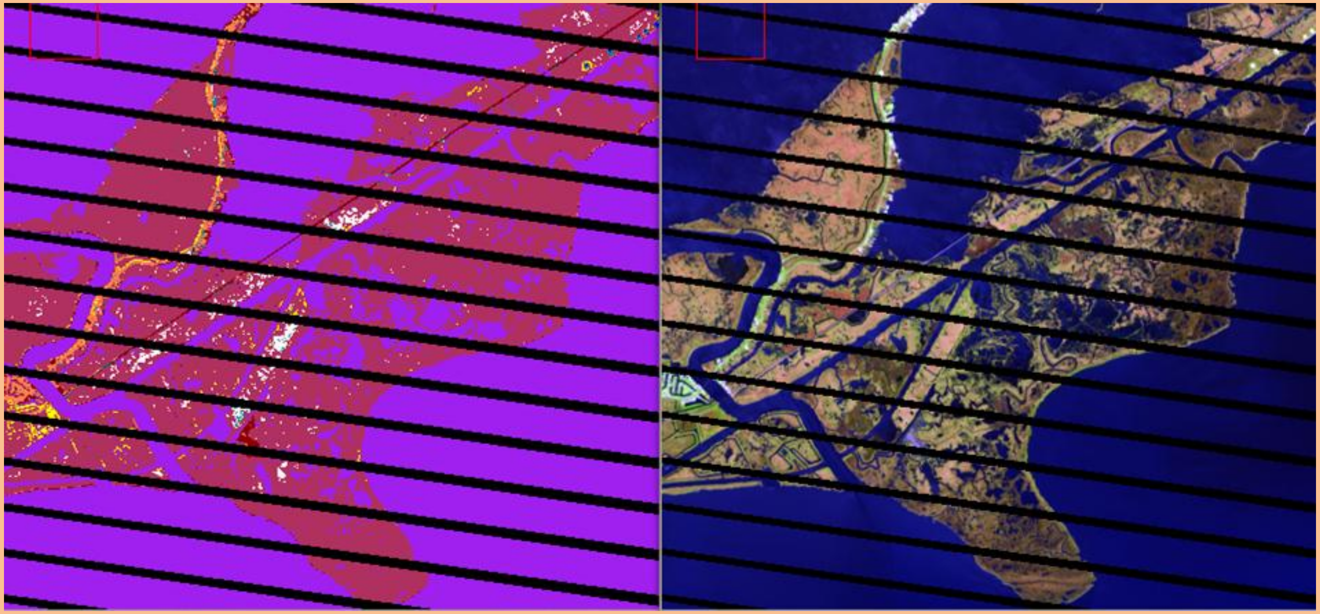
Landsat 8 Random forest classification results Landsat 8 underfly band 6, 5, 4 composite
(87 X 87 pixels)



Landsat 7 Random forest classification results

Landsat 7 band 5, 4, 3 composite

(400 X 400 pixels)



Landsat 8 Random forest classification results

Landsat 8 underfly band 6, 5, 4 composite

(400 X 400 pixels)

2 Land Cover Mapping Accuracy Assessment

- Classification results from L7 and L8 agree (86%)

Overall Accuracy = (220/250) 88.0000%
Kappa Coefficient = 0.8465

Ground Truth (Pixels)

Class	wetland brown	wetland green	forest	barren	herb	water	low den res	high den res	cropland	other	Total
Unclassified	0	0	0	0	0	0	0	0	0	0	0
wetland brown	15	1	1	2	1	3	0	0	0	1	24
wetland green	0	31	10	0	0	0	0	0	0	0	41
forest [Green	0	1	33	0	0	0	0	0	0	0	34
barren [White	0	0	0	9	0	0	0	0	0	0	9
herb [Sea Gre	0	0	1	0	7	0	0	0	0	0	8
water [Purple	0	0	0	0	0	97	0	0	0	0	97
low den res [	0	0	0	0	0	0	17	1	0	0	18
high den res	0	0	0	0	0	0	1	7	0	0	8
cropland [Cya	1	0	1	1	1	0	1	0	3	1	9
other [Blue]	0	0	0	1	0	0	0	0	0	1	2
Total	16	33	46	13	9	100	19	8	3	3	250

- Classification results in areas that disagree between L7 and L8 (14%)

Landsat 8 underfly

Overall Accuracy = (175/250) 70.0000%
Kappa Coefficient = 0.6065

Ground Truth (Pixels)

Class	wetland brown	wetland green	forest	barren	herb	water	low den res	high den res	cropland	other	Total
Unclassified	0	0	0	0	0	0	0	0	0	0	0
wetland brown	8	3	5	3	0	4	1	0	0	0	24
wetland green	0	10	16	0	0	0	3	0	0	0	29
forest [Green	0	3	93	0	0	0	0	0	0	0	96
barren [White	2	0	1	18	3	0	1	0	0	0	25
herb [Sea Gre	0	0	0	0	12	0	2	0	0	0	14
water [Purple	0	0	0	0	0	3	0	0	0	0	3
low den res [	3	2	5	2	2	0	25	0	0	1	40
high den res	0	1	0	0	0	1	2	5	0	0	9
cropland [Cya	0	0	0	0	3	0	4	2	1	0	10
other [Blue]	0	0	0	0	0	0	0	0	0	0	0
Total	13	19	120	23	20	8	38	7	1	1	250

Landsat 7

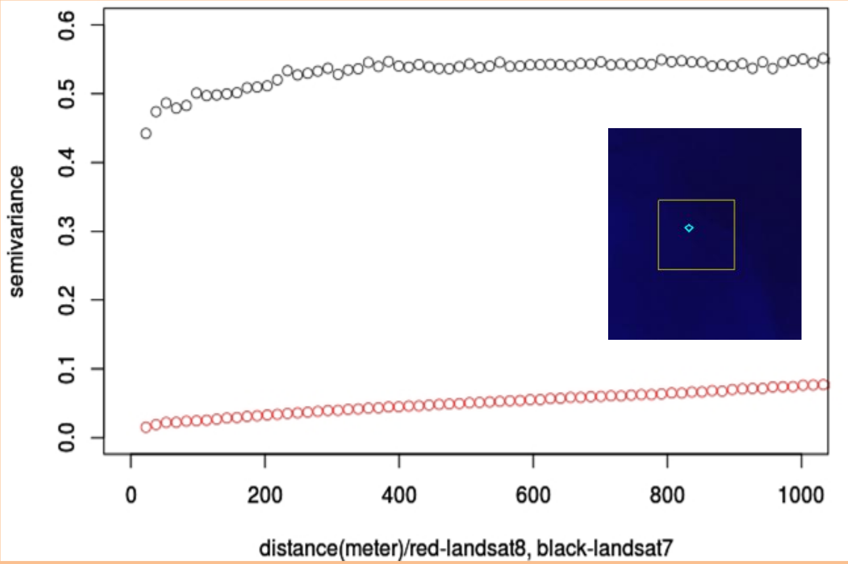
Overall Accuracy = (43/250) 17.2000%
Kappa Coefficient = 0.0705

Ground Truth (Pixels)

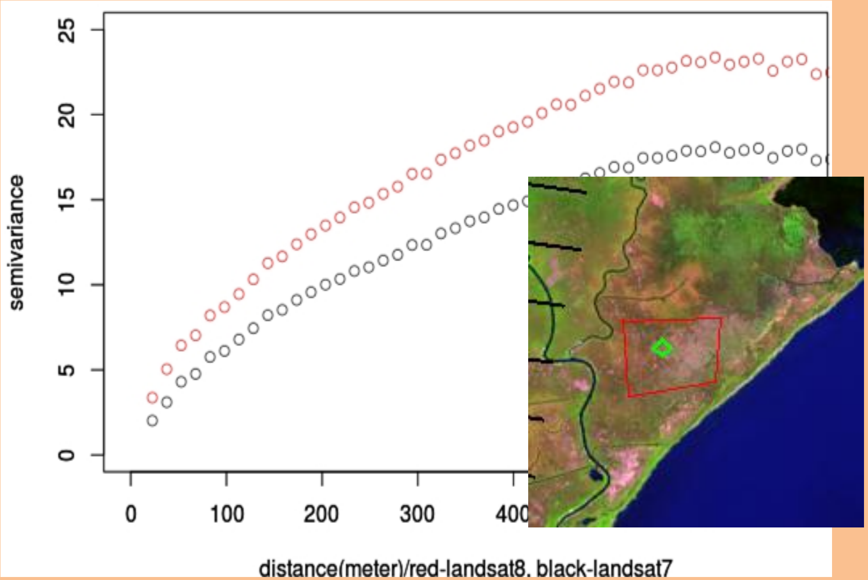
Class	wetland brown	wetland green	forest	barren	herb	water	low den res	high den res	cropland	other	Total
Unclassified	0	0	0	0	0	0	0	0	0	0	0
wetland brown	3	2	6	13	7	1	15	0	0	0	47
wetland green	7	9	96	2	5	1	6	0	0	0	126
forest [Green	0	8	15	0	2	0	1	0	0	0	26
barren [White	0	0	1	3	4	0	1	0	0	0	9
herb [Sea Gre	0	0	1	0	1	0	3	0	0	0	5
water [Purple	0	0	0	0	0	4	0	1	0	0	5
low den res [	0	0	0	0	1	0	6	1	0	0	8
high den res	0	0	0	0	0	0	1	2	1	0	4
cropland [Cya	3	0	1	5	0	0	4	0	0	1	14
other [Blue]	0	0	0	0	0	2	1	3	0	0	6
Total	13	19	120	23	20	8	38	7	1	1	250

Variograms of Landsat 7 vs Landsat 8 underfly (NIR band in radiance)

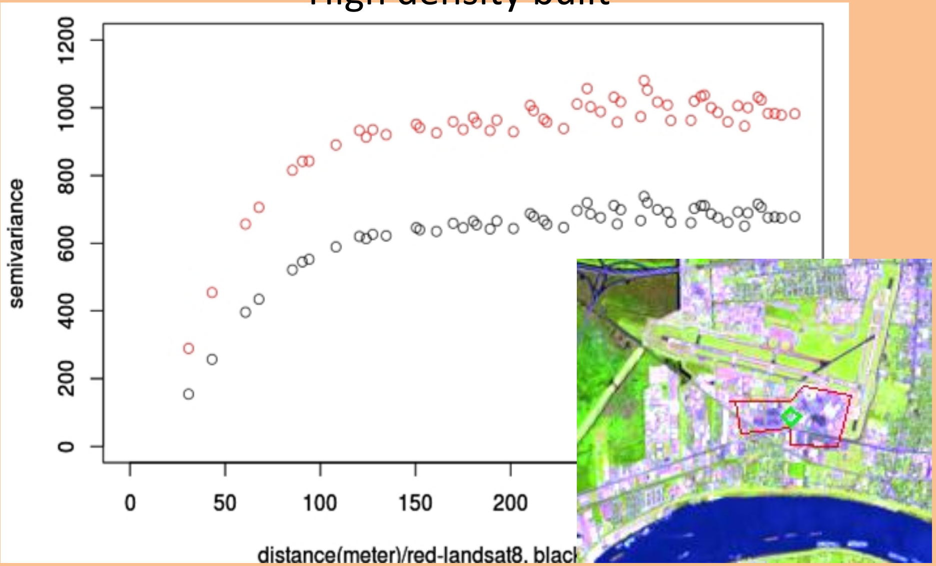
Water



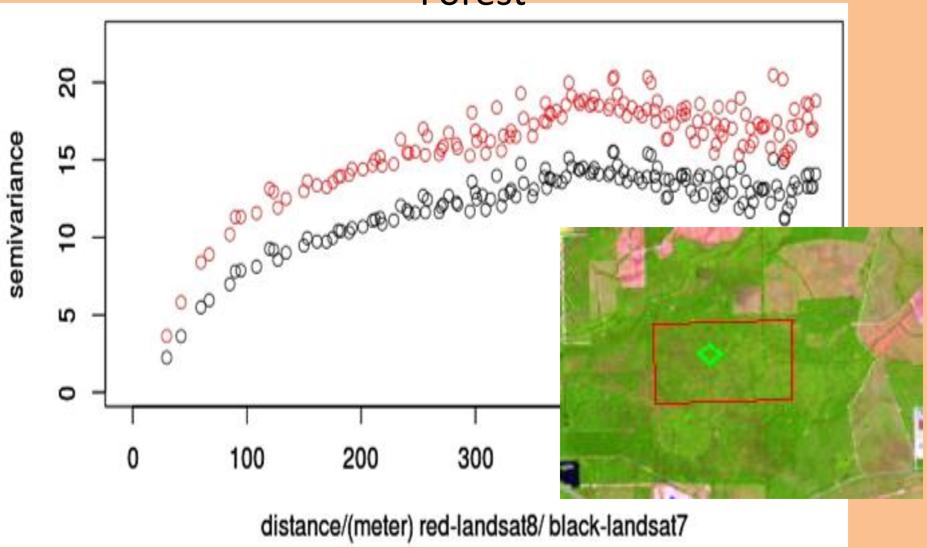
Wetland



High density built

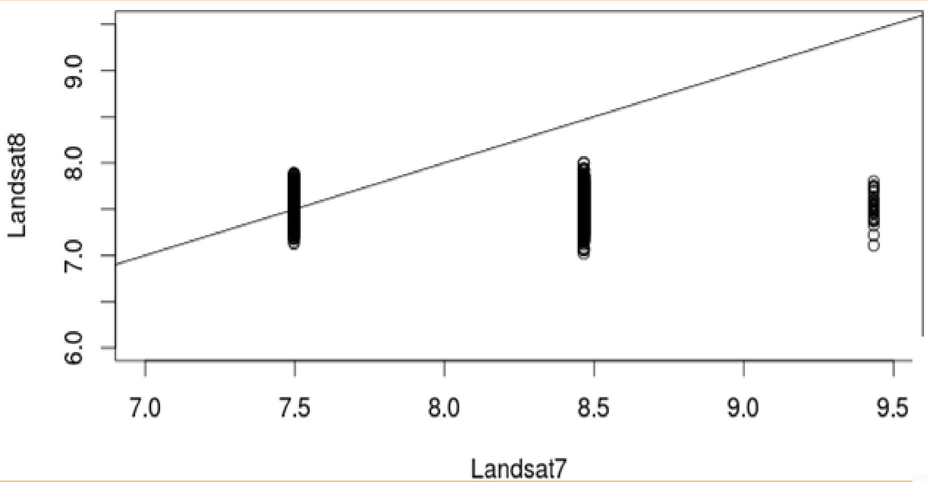


Forest

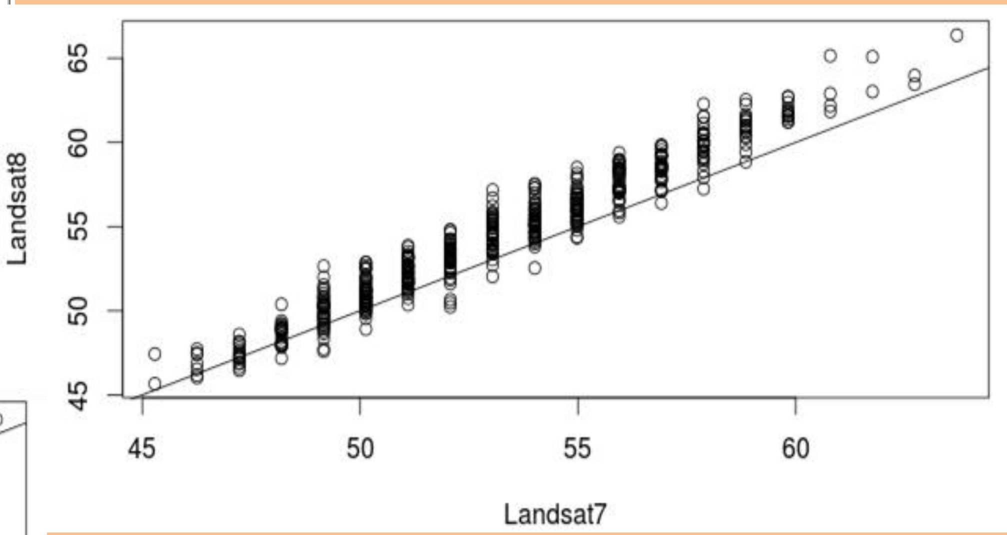


The NIR bands of Landsat 7 and Landsat 8 underfly

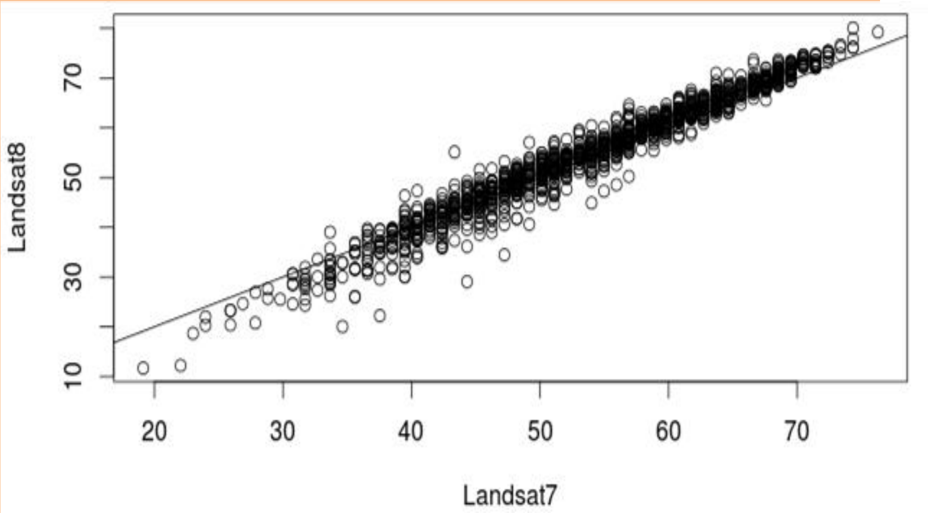
1. Water



2. Forest

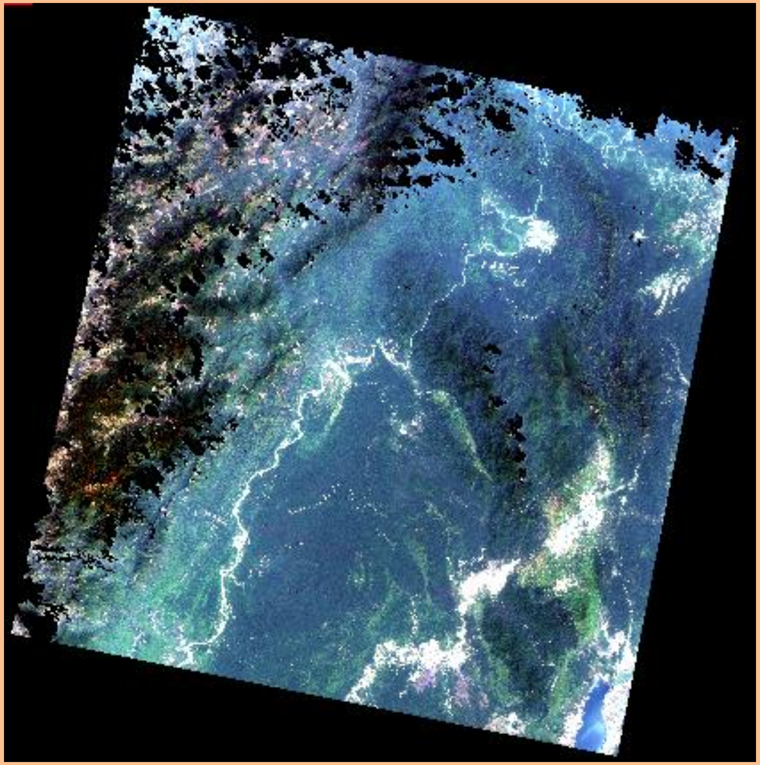


3. Wetland

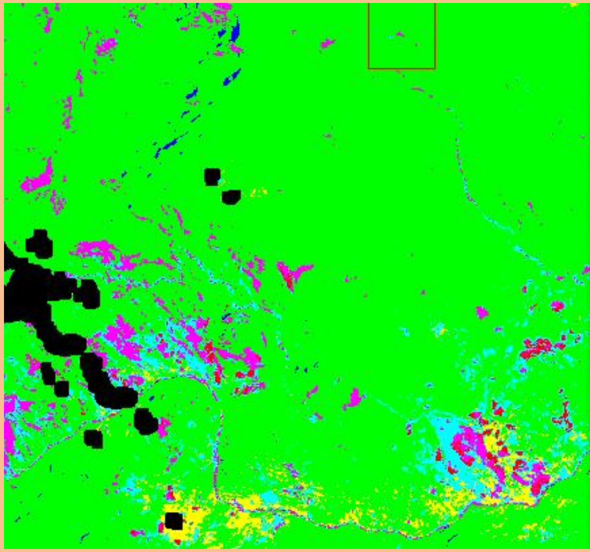


Comparison analysis of land cover classifications using Landsat 8 OLI/TIRS Pre-WRS-2 and Landsat 7 ETM+ data under the influence of cirrus clouds

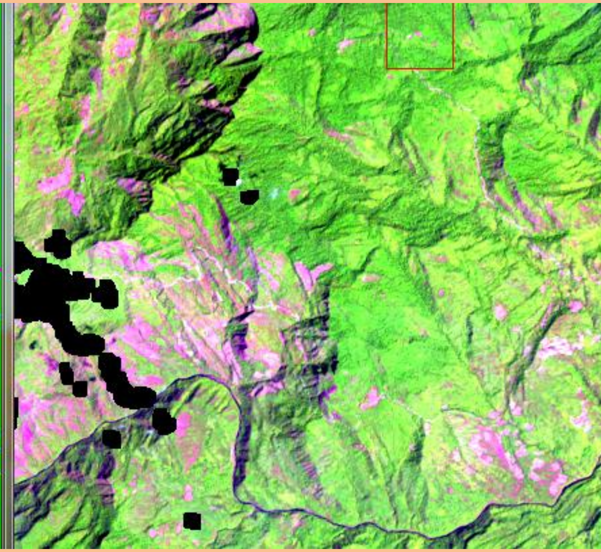
1. Data: p134 r42
2. Date: 03/30/2013
3. Location: Northern Burma
4. Fmask
5. Bands used
    - Landsat 8: 2, 3, 4, 5, 6, and 7
    - Landsat 7: 1, 2, 3, 4, 5, and 7
6. Classification algorithm: Random Forest



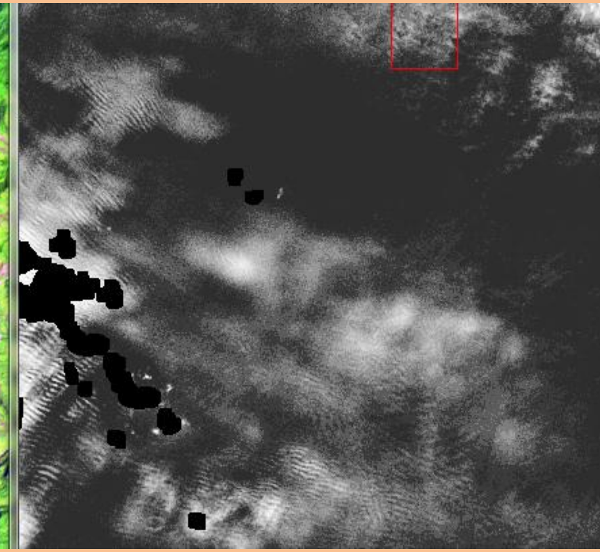
Landsat 8 underfly classification map



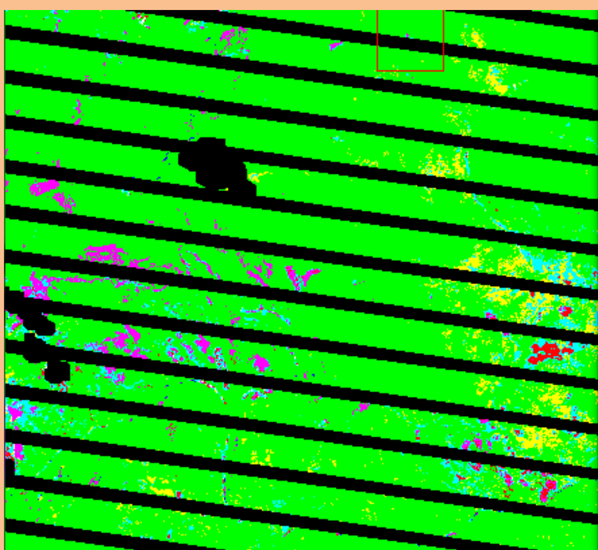
Band 6, 5, 4 composite



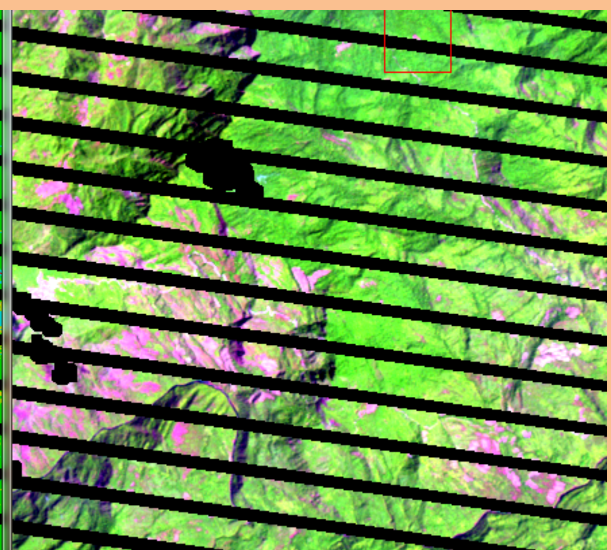
Band 9



Landsat 7 classification map



Band 5, 4, 3 composite



Conclusions

- Potential for dramatic improvement in detection of clouds and cloud shadows – in particular thin clouds that have previously gone undetected and undermine many uses – particularly time series analysis for monitoring land cover change or trends in condition.
- Image classification accuracies are improved using L8 vs L7 due to improved radiometric resolution/SNR
  - (need to work more on the question of the effect of previously undetectable clouds on classification)
- Time series approaches open new opportunities for producing “composited” images (or whatever you want to call them)
- Variograms show L8 data have reduced noise (expected) and increased variance (not sure why – maybe finer spatial resolution)

My “two-cents” worth

- There is no going backward on radiometry – “everything is going to improve with improved radiometry”
- The cirrus band (and cloud and shadow detection, in general) is critical to the next generation of applications and products
- Increased frequency of observations remains the next “big step forward” in moderate resolution land imaging
- Use of L8 in time series analysis dependent on ability to atmospherically correct L8 data to surface reflectance